Chapter 18

Cockpit Voice and Flight Data Recorders

Fairchild

Recording information in flight is among the most valuable methods of determining the cause of airplane accidents. There are several types of recorders, some required by law, others installed because they reduce the cost of maintenance. In the newest airliners hundreds of points are measured on engine, airframe, hydraulic, pneumatic and other systems. When downloaded later on the ground, the data often warns of trouble well in advance of a full-blown inflight problem. Another trend, now possible with worldwide satellite communications, is to transmit flight data as it is collected, and downlinking it to a maintenance facility even before the airplane lands.

Two devices required in airliners and other high-performance aircraft are the CVR (cockpit voice recorder) and FDR (flight data recorder). These are the "black boxes" mentioned by news reporters following an air disaster. As seen above, they are not black but a bright "international orange" used on emergency equipment for high visibility.

An improvement in flight recorders is the transition from recording on tape to storing data on solid-state memories. Not only does it improve reliability, but stores far more data. Early recorders required high maintenance, and tapes often fouled in the mechanism, losing valuable accident information.

CVR Basics

A typical CVR is required (by U.S. law) to record for at least 30 minutes, then start again, while erasing the previous 30 minutes. In other countries the requirement is 120 minutes. After the airplane lands safely, the pilot may bulk-erase the tape. Erasing is not possible in flight because the erase circuit is disabled unless the system senses the airplane is on the ground. This is usually done by a weight-on-wheels, or "squat switch."

The new CVR's are easier to download than early models. Instant playback is possible with a portable device. Any place on the recording is quickly located by forward, reverse and stop commands.

The power source can be either 115 volts 400 Hz or 28 VDC. With so few moving parts, the solid-state CVR requires no periodic maintenance or scheduled overhaul.

Inertial Switch. If a CVR continues to receive aircraft power after a crash, the recorded audio is wiped clean and lost. This is prevented by an inertial switch. It responds to high G forces of a crash by interrupting power to the voice recorder.

Audio Channels. The CVR provides four audio channels into the recorder:

Captain: Any microphone used by the captain, such as the normal boom mike, as well as the mike in an oxygen mask or hand mike. This assures a recording of radio communications.

Co-Pilot (First Officer) The same as for the captain.

Public Address (PA) This channel picks up announcements by the crew to passengers in the cabin.

Cockpit Area Mike. This is designed to pick up crew member voices and other sounds in the cockpit. There have been problems with cockpit area mikes. After a crash, safety investigators often complain that audio from the cockpit area mike is impossible to hear because it's drowned out by nearby loudspeaker audio. Not only does this eliminate important conversation between pilots, but sounds which can point to problems---sounds such as changes in engine speed, switch clicks and flap motors. A technician must follow the manufacturer's installation instructions carefully for good cockpit area pickup. In airline installation, the airframe manufacturer will have determined all locations. In General Aviation, where there is a choice for locating the area microphone, typical techniques include using a directional microphone facing the crew and one that is noise-cancelling.

Fairchild

Manufacturers of flight data recorders must comply with standards for survivability in a crash. A recorder should withstand a temperature of 1100 degrees C for 30 minutes, as shown in this test. In another test, a 500-pound weight is dropped on the recorder from 10 feet.

Line replaceable unit (LRU) for a cockpit voice recorder shown located in the aft fuselage of a Learjet. It is usually on the pressurized, or cabin, side.

Cockpit area microphone picks up conversation between pilots and other sounds that provide clues for accident investigators. This mike is located atop the glareshield on a small corporate jet. In airliners, the mike is usually above, on the overhead panel.

Underwater Locating Device

Both cockpit voice and flight data recorders are required to be fitted with a ULD, or underwater locating device. They are also known as ULB, for underwater locator beacon. Each recorder usually has one, but when both CVR and FDR are located next to each other and are not likely to become separated during a crash, a single ULD may, in some cases, be used.

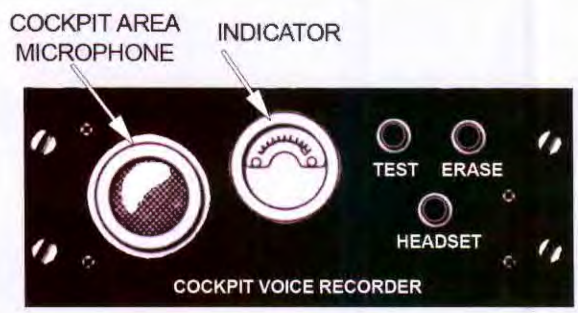
Most ULD's are "pingers," sending out an ultrasonic tone on 37.5 kHz, which is too high for human's to hear. (The high frequency is more effective for homing on with a listening device.)

The ULD is triggered when moistened by water (salt or fresh). It must start pinging no more than four hours after the airplane goes underwater, then continue to broadcast for at least 30 days. It is rated to perform at depths up to 20,000 feet. (The average depth of the world's major oceans is 13,000 feet.)

Flight Data Recorders (FDR)

The second "black box" needed by crash investigators is the Flight Data Recorder. Early FDRs used a sharp-pointed stylus to scratch lines into a band of thin steel. Although the steel "memory" resisted heat and flames, it had low capacity for storing information. Like the cockpit voice recorder, the FDR is always a bright orange.

Under pressure from accident investigators for more parameters (measuring points), the FAA required



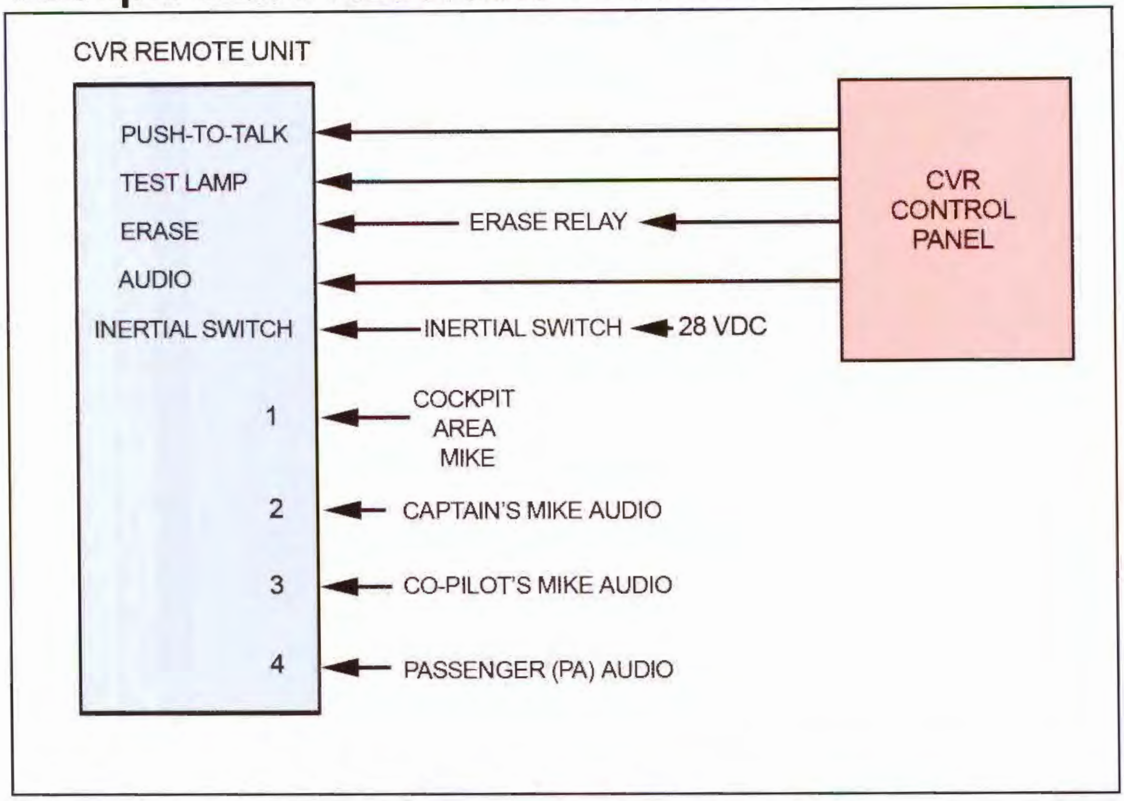
Controller for a cockpit voice recorder (early type). The cockpit area microphone picks up sound of pilot conversation, airplane, engine mechanical noises and warning tones.

To check the system, the test switch is held down for five seconds; if OK, a green light illuminates. If it doesn't light in six seconds, the CVR must be removed for service

The erase switch works only when the airplane is on the ground (either a cabin door must open, a squat switch energized or other interlock). Erasing is indicated by an audio tone.

The headset jack enables pilot or technician to plug in and hear if audio is distorted; he speaks into the cockpit area mike and listens to the playback quality on headphones.

Cockpit Voice Recorder: Interconnect

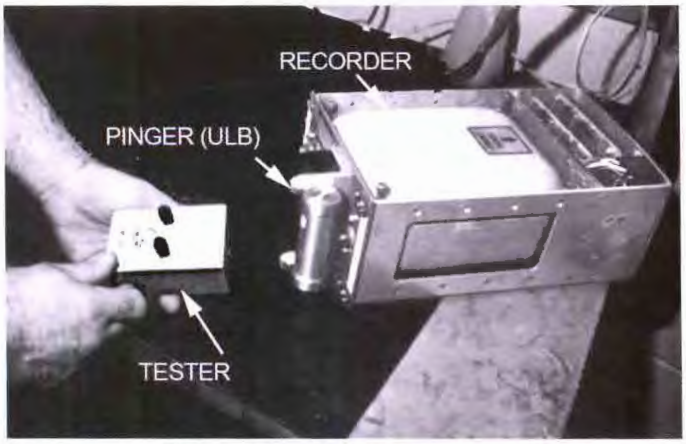


Line Replaceable Unit, at left, is mounted in the aft fuselage in a crash-hardened housing. It records four audio channels; captain's mike, co-pilot's mike, cockpit area mike and public address. Test and erase functions are done at the controller on the instrument panel (right).

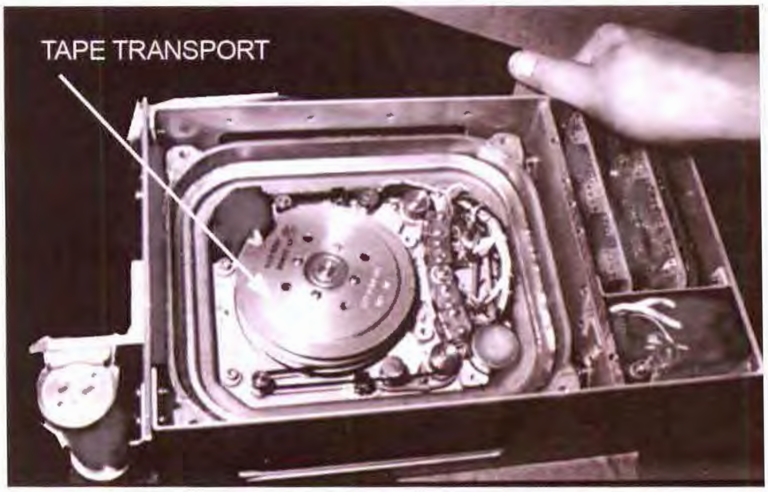
Erasing the tape can only happen after the airplane is safely on the ground. This function is protected by an external "squat," or weight-on-wheels switch.

The inertial switch reacts to forces of a crash and shuts off power to prevent the tape from running and erasing the last 30 minutes.

Although the CVR tape is rated for 30 minutes of recording in the U.S., other countries require 120 minutes.



When testing the underwater locator beacon (the "pinger") the tone is ultrasonic and cannot be heard by the ear. The tester receives the tone and converts it down to the range of human hearing. To start the pinger operating, one end is moistened to simulate an underwater condition.



Early cockpit voice recorders use a tape and mechanical drive. Next-generation recorders eliminate tape with more reliable solid-state memory. New recorders meet tougher requirements for heat and G-forces and need less maintenance.

large aircraft be equipped with digital flight data recorders of greater capacity and reliability. Depending on date of manufacture all such airplanes had to retrofit anywhere from 22 up to 57 parameters. Aircraft manufactured after 2002 require 88 parameters.

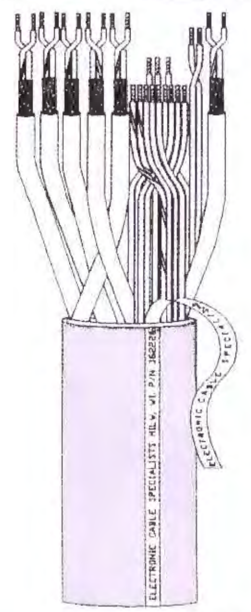
FDR's grew even more important with the arrival of electronic instruments. In airplanes with mechanical gauges, accident investigators could look at an airspeed needle pinned in place by the crash and obtain valuable information (such as airspeed when the airplane struck the ground). They could tell if warning lights were on or off at the time of impact by looking at condition of filaments in the bulbs. But as this information went from instruments, switches and lamps to electronic displays, it disappeared when the screen went dark. Thus the urgency of storing data on a flight recorder.

Many in the aviation industry want to add to the present generation of flight data recorders. One idea is to equip large aircraft with two recording systems; forward and aft, to assure sufficient data. There is also a move to equip the cockpit with a video camera. Video images stored in the FDR could yield valuable information about what happened just before the crash.

The digital FDR (DFDR) takes analog signals (heading, altitude, airspeed, etc.)--which usually vary in a smooth, continuous fashion and converts them to digital format for storage in a solid-state memory. Some signals are "synchro," meaning signals from electromechanical instruments. Yet another type of input is from the aircraft databus, such as ARINC 429, which is a stream of data from many aircraft systems.

Unlike the old, mechanical recorder, there is no scheduled overhaul and little maintenance for digital models. Reliability extends to 20,000 hours (on average) before failure and data is easily recovered with a portable unit. A typical flight data recorder stores 25 hours of information before starting over again.

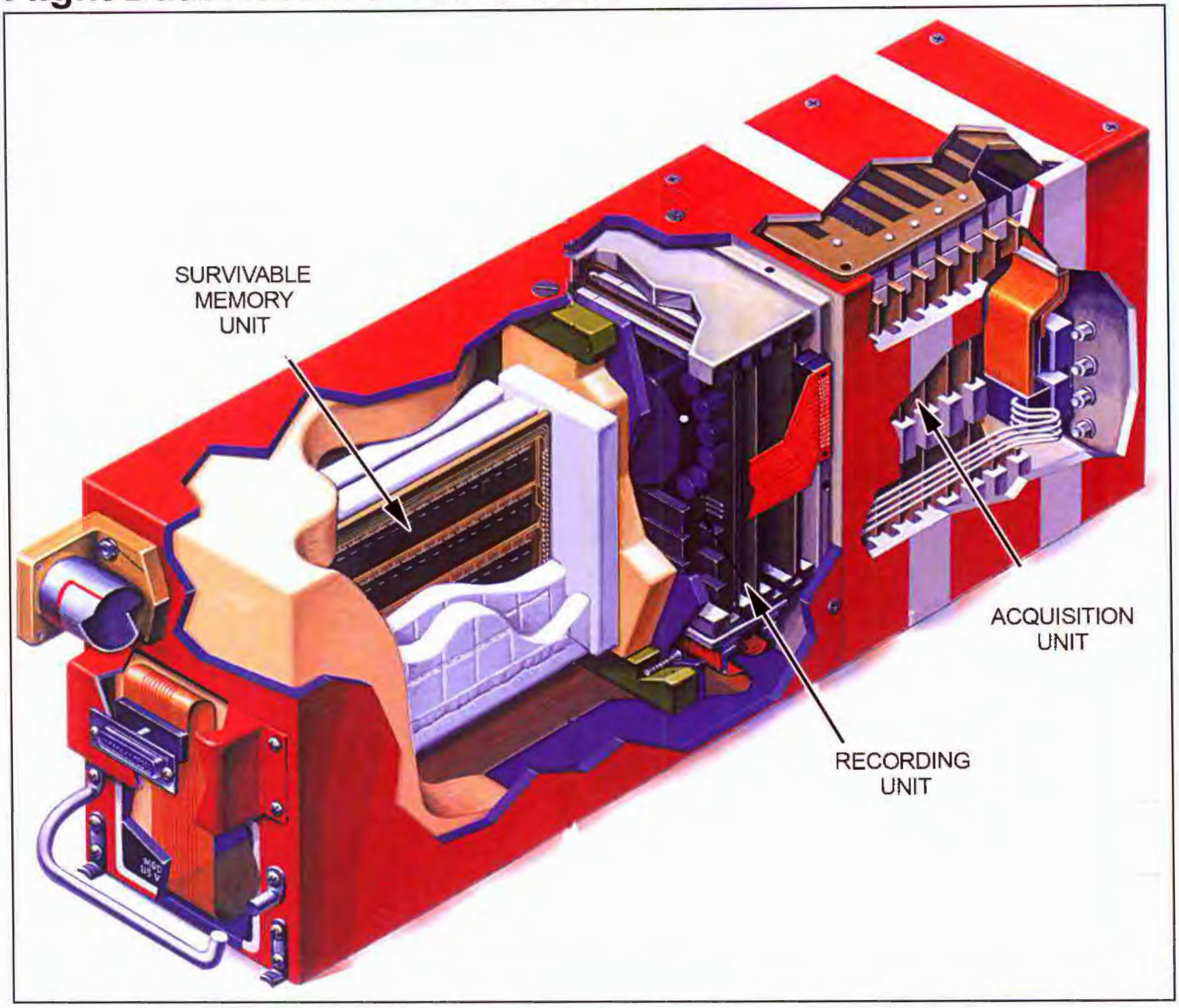
Cable Assemblies



ECS

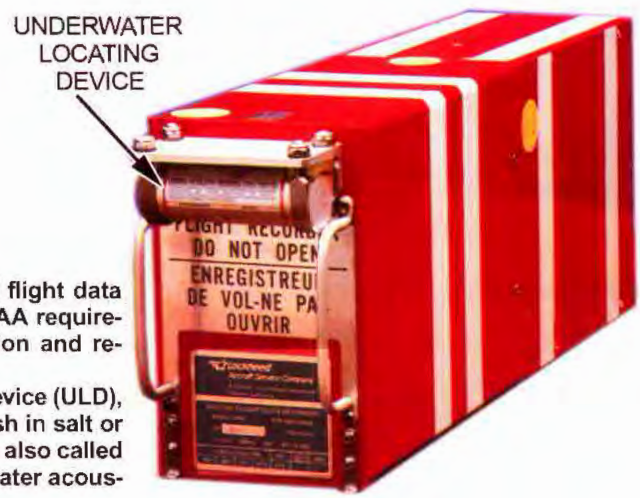
Cable assembly for a cockpit voice recorder. It has 6 pairs of twisted and shielded cable, plus 14 other conductors. They're protected against chafing by an outer jacket. This harness, which conforms to ARINC 557, can be obtained prewired from such companies as ECS.

Flight Data Recorder: Solid-State



Solid-State Flight Data Recorder (SSFDR) by Lockheed eliminates tape storage with a survivable solid-state memory. It is interchangeable with earlier-generation recorders without wiring changes.

The system uses direct recording, which eliminates data compression. This permits the memory (non-volatile flash) to be downloaded without a delay of 8-10 hours. The unit doesn't have to be removed from the airplane to retrieve stored data and is done with a PC. Unlike early recorders this one has much greater MTBF (mean time between failures) of 20,000 hours and requires no scheduled overhaul.



Another recorder type (at right) is the digital flight data recorder (DFDR). It is designed to meet an FAA requirement for an expandable flight data acquisition and recording system (EFDARS).

All recorders have an underwater locating device (ULD), seen on this model. It is triggered after a crash in salt or fresh water and emits an ultrasonic tone. It is also called a ULB (underwater locator beacon) or underwater acoustic beacon.

Information Stored by Digital Flight Data Recorder (36 Parameters)

1. Begin recording prior to takeoff:
a. Record time of flight control check (hold flight controls at full travel for 2 to 5 seconds, each position).
b. Takeoff flap Setting.
c. Takeoff thrust setting.
d. Brake release time.
e. Rotation Speed (VR) and time of rotation.
f. Aircraft attitude after rotation.

2. During stabilized climb (wings level) after take-off record:
a. Altitude and time at which climb stabilized.
b. Airspeed.
c. Vertical speed.
d. Pitch attitude.
e. Displayed angle of attack.
f. Heading (note true or magnetic).

3. During level flight (wings level) at maximum operating limit speed (VMO./MMO) or at VMAX record:
a. Altitude and time at start of level flight.
b. Airspeed.
c. Ground speed and time at which recorded (three times).
d. Outside or total air temperature.
e. Automatic Flight Control System (AFCS) Mode and engagement status including autothrottle.
f. Pitch attitude.
g. Displayed angle of attack.
h. Heading (note true or magnetic).
i. Drift angle and time at which recorded (three times).
j. All displayed engine performance parameters for each engine.
k. Altitude and time at end of level flight.

4. During a banked turn (90° to 180° heading change) record:
a. Altitude, heading and time at beginning of turn.
b. Stabilized roll attitude (bank angle).
c. Altitude, heading and time at end of turn.

5. During stabilized (wings level) descent, record:
a. Altitude and time at which descent initiated.
b. Airspeed.
c. Pitch attitude.
d. Displayed angle of attack.
e. Heading (note true or magnetic).
f. Altitude and time at which leveled off.

6. During approach at level flight (wings level) deploy flaps throughout the flap operating range
in all available settings (or at 5° increments) and hold for 5 seconds at each setting. Record:
a. Altitude and time at beginning of flap deployment sequence.
b. Flap setting and time when each setting is reached.
c. Altitude and time at end of flap deployment sequence.

7. During final approach, record:
a. Altitude and time at beginning of final.
b. Radio altitude and time at which recorded (three points).
c. Localizer deviation and time at which recorded (three times).
d. Glide slope deviation and time at which recorded.
e. Time of outer marker passage.
f. Time of landing gear deployment.
g. Final flap setting.
h. Time of inner marker passage.

8. During landing and rollout, record:
a. Time when thrust reversers deployment sequence was initiated.
b. Ground spoiler or speed brake setting and time ground spoiler deployed.

9. During all flight phases, record:
a. Time of any three radio transmissions from each flightcrew position.
b. Any warning or caution lights that illuminated and the time at which they illuminated.

Review Questions
Chapter 18 CVR and FDR

18.1 A CVR is required to record for _______ minutes before erasing and recording again.

18.2 What is the purpose of an inertial switch?

18.3 Name the four audio channels into a CVR.

18.4 What is the purpose of the cockpit area mike?

18.5 The erase switch on a CVR works only ___________.

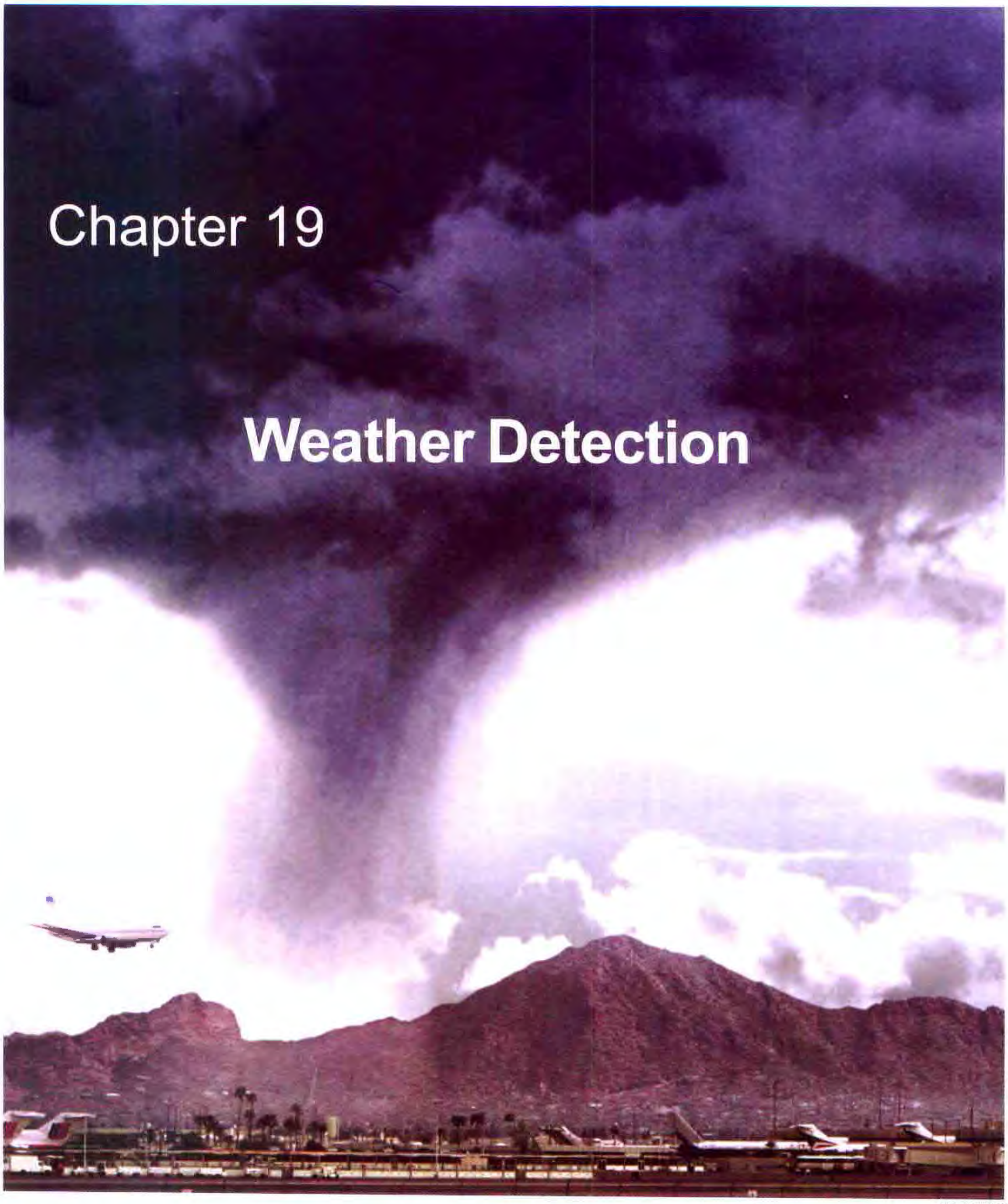
18.6 How long must an Underwater Locating Device send signals after an aircraft ditches in the water?

18.7 FDR's for aircraft manufactured after 2002 must record up to ____ parameters.

18.8 The solid-state FDR replaces tape storage with __________.

Chapter 19

Weather Detection



Honeywell

The thunderstorm cell shown above is producing a"microburst," a powerful downdraft and outflow from its central core. Once the cause of many airline accidents, it is no longer a major problem. Windshear devices that give warning are aboard all commercial airliners.

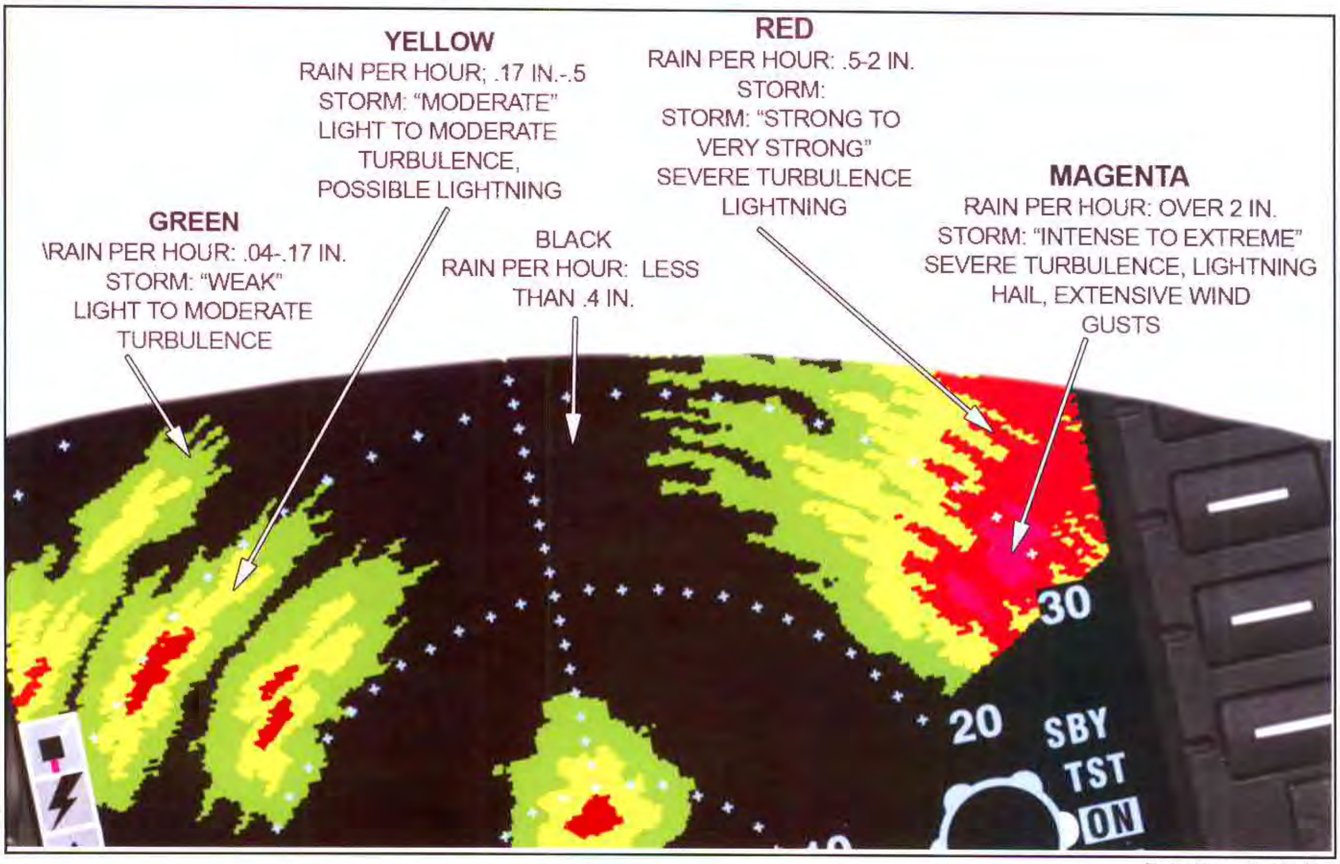
The earth is a weather factory generating many hazards to flight; thunderstorms, lightning, fog, turbulence, haze, hail, rain, blowing snow and windshear. Nevertheless, airliners complete their scheduled flights 98.7 percent of the time. Much of this success is owed to a network of weather-reporting stations on the ground which deliver timely information to the pilot. Just as important is weather-detecting equipment aboard the airplane to sense dangerous conditions ahead and help the pilot plan an escape route.

One of the greatest weather threats to aircraft is the thunderstorm. Few aircraft have the performance or structural strength to withstand turbulence generated inside storm clouds. It's proven especially deadly when the airplane is arriving or departing the airport and is low to the ground, where it is known as "wind shear."

Clear Air Turbulence

Another hazard is CAT, for clear air turbulence. It occurs at high altitudes of the jet stream between fast-moving currents of air. Because the air masses

Color-Coding the Radar Display



Radar image: Bendix-King

The radar image uses five colors to indicate severity of weather; black, green, yellow, red and magenta (a purple-red). The colors are based on the rate of rainfall in inches per hour. Rainfall is also a guide to turbulence in clouds. A pilot may enter the green region, he tries to avoid the yellow, and carefully flies around red and magenta.

Weather on Multifunction Display

Avidyne Flight Max

More aircraft are now outfitted with multifunction displays which overlay several sources on a basic moving map. This includes weather (rain or other precipitation) and lightning strikes. The information may be picked up by satellite or from an onboard radar or Stormscope.

Besides weather, the displays show traffic and terrain hazards.

move in different directions, an airplane hits heavy turbulence when it enters the boundary between them. The damage is usually not to the airplane but to passengers. They are tossed about and injured in the cabin (thus the request to keep the seat belt buckled.)

Thunderstorms

Because thunderstorms are accompanied by lightning, the earliest attempt at detection was the ADF, or automatic direction finder, already aboard many aircraft. Lightning is an electrical discharge that generates not only flashes of visible light but radio frequencies in the low- and medium-frequency bands. The ADF receiver, therefore, responds to this energy. With each lightning discharge, the ADF needle dips away from its rest position. According to the folklore of aviation (which many pilots believe) an ADF needle points toward the storm. This is dangerous because the needle and its mechanism do try to point to the storm, but swing too slowly. As the lightning discharges in different directions, the needle lags behind, becoming confused and erratic. But as we'll see, lightning can provide valuable information about storm location.

Types of Detection

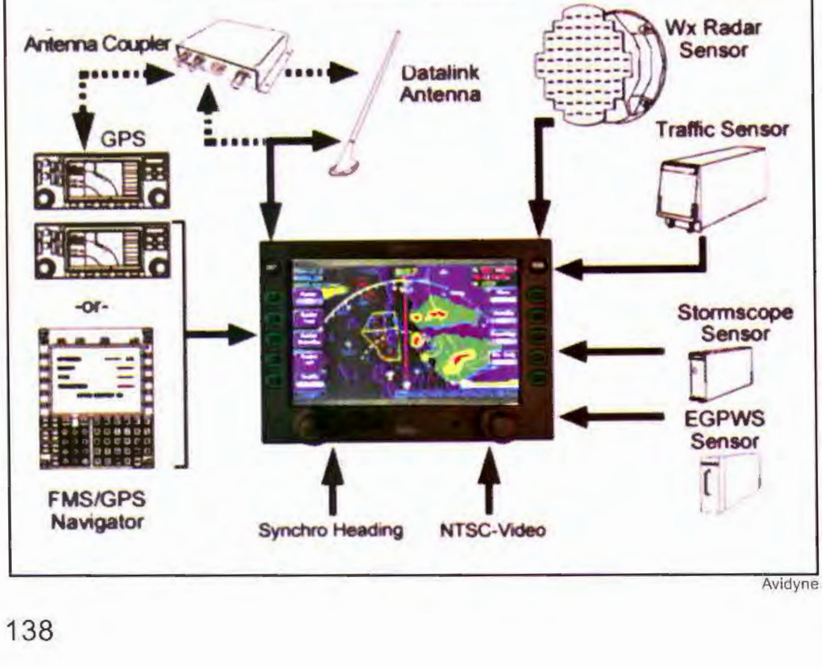
Weather Radar. The leading airborne weather-detecting device, first put aboard a DC-4 airliner in 1946, is weather radar. Adapted from military models of World War II, it proved so effective it became required equipment aboard all commercial flights. The radar system operates on the principle of reflectivity; a pulse emitted from the radar antenna strikes water droplets in a cloud and reflects back as an echo. By plotting the strength and direction of the echoes, areas of heavy rain are "painted" on a graphic display, and form an outline of thunderstorm cells. The first radars were monochrome, showing rain intensity in shades of gray. Present-day radars give a much clearer presentation in color.

Weather radar has been much improved in recent years. It is less prone to an early problem, known as "attenuation," where an area of moderate rain blocks echoes from a more turbulent cell behind it. Newer radars are less responsive to "ground clutter," where radio energy strikes the ground and interferes with the image. Modern radars can present a vertical, or profile, view of the storm, showing the height of the clouds, which is a good clue to storm intensity.

The most significant development for weather radar in recent years is turbulence detection. The first radars could only sense rain as it fell in the vertical direction. By the 1980's, however, designers could build radar sets which also measure the *horizontal* movement of rain. Although very heavy rain is usually a good indicator of turbulence, rain that moves horizontally is a sure sign of powerful, dangerous winds.

The new radars detect this with a turbulence detection system based on the doppler shift. If a radar pulse hits a rain drop moving horizontally away from the airplane, the returning pulse is slightly reduced in frequency (the doppler shift). When the rain drop moves toward the airplane, the echo frequency rises in frequency. (It's the same doppler shift that causes a train whistle sound to higher in pitch as it approaches; the waves are squeezed together and you hear a rising tone. After the train passes, the waves stretch out, causing a lower frequency.)

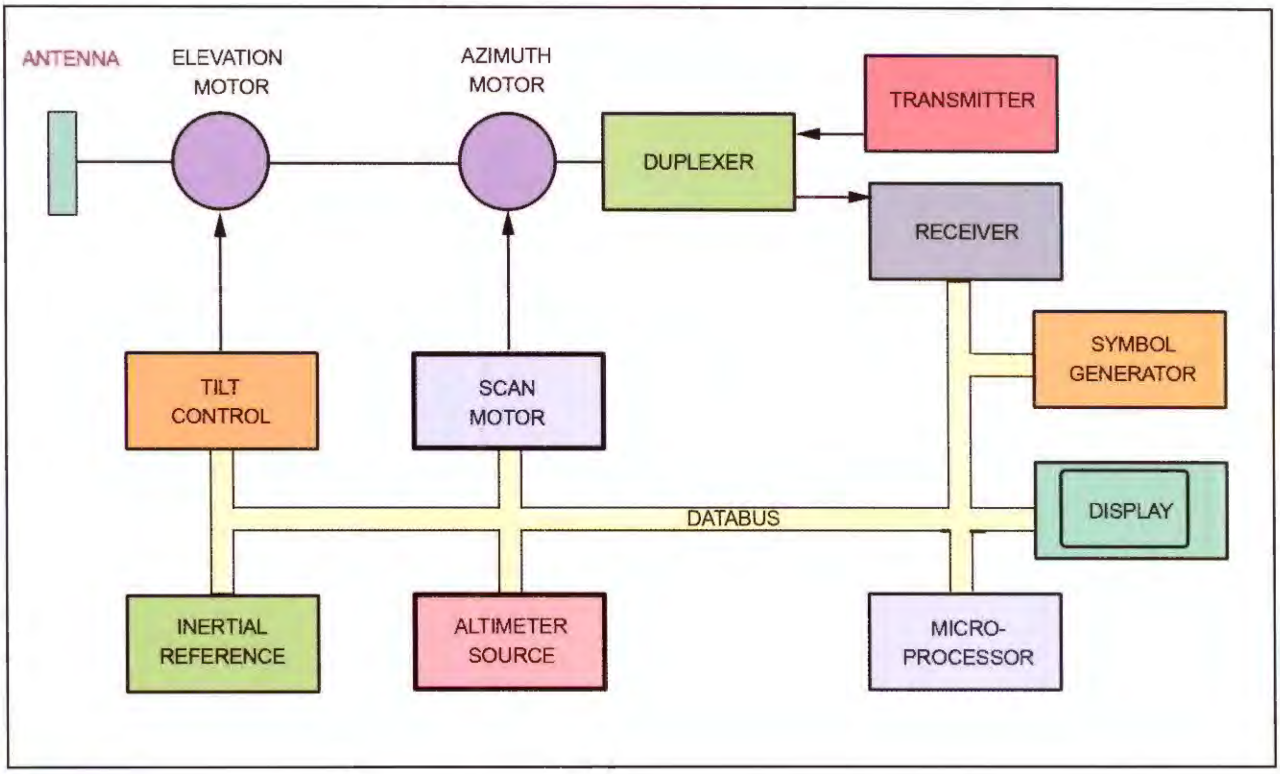
Sensors for Multifunction Display



Avidyne

Many sensor and data inputs are required to drive the MFD. The system has standard industry interfaces (such as ARINC 429 and IEEE RS-232), as well as interfaces to accept signals from other manufacturers' products for radar, lightning, terrain and traffic information.

Weather Radar Transmitter-Receiver



Antenna

A single antenna located in the nose transmits radar pulses and receives echoes from rain and other precipitation.

Elevation Motor

Raises and lowers the antenna vertically to keep it stabilized on the same area of the sky, even as the airplane nose moves up or down.

The elevation motor also enables the pilot to "tilt" the antenna to keep it just above the horizon and avoid receiving echoes from the ground. The radar, however, may operate in a "mapping" mode, which provides an image of the ground, if desired. (One example; when approaching a coastline.)

The latest application for elevation is "vertical profile radar." The motor sweeps the antenna vertically to show the height of the clouds, an indication of the storm's strength. The typical tilt range in a weather radar is plus and minus 15 degrees.

Azimuth Motor

This sweeps the antenna from side to side in a scanning motion.

Inertial Reference

The inertial reference senses aircraft pitch and roll and provides information required by elevation and azimuth motors to stabilize the antenna. The inertial source may be laser gyros or electromechanical gyros which also operate the airplane's flight attitude instruments.

Duplexer

In order for one antenna to serve both transmitter and receiver, a "duplexer" is used. It directs radio energy from the transmitter to the antenna, and connects the receiver to the antenna for receiving returning echoes.

Microprocessor

This microcomputer converts switch positions selected by the pilot into digital words and applies them to one or more databuses. It also computes the azimuth and elevation of the antenna to keep it stabilized.

Transmitter

The transmitter sends out pulses of radio energy, usually on 9.333.8 MHz. The receiver then listens for echoes between pulses.

Receiver

The strength of echoes varies according to the rainfall rate and they are divided into colors for the display; black, green, yellow and red.

The most recent is the color magenta, for turbulence. In this mode, the receiver measures *horizontal* movement of rain, which is a measure of turbulence. Under the Doppler effect, the returning echo rises or falls in frequency, depending on the direction of the rain drop.

When the radar is set to the turbulence mode, the number of pulses transmitted per second increases from several hundred per second to over 1000 per second. This is because stronger echoes are required to measure the very small frequency change. Also, the turbulence mode has a range of less than 50 miles. This limit occurs because a high pulse rate allows little time for the echo to return to the airplane before the next pulse is transmitted.

Symbol Generator

This section converts weather information from a digital form into graphics that can be displayed for the pilot.

Early radar did not have circuits which could measure doppler shift. They were too unstable to measure small frequency changes. Today's radars use solid-state devices that generate precise frequencies and have the stability to measure frequency shifts in the returning echo. As seen in the illustration, turbulence is shown on the radar screen by the color magenta.

Single Engine Radar. Mounting radar in a light aircraft has been a problem because the antenna interferes with the propellor and engine. To avoid this area, the radar antenna is slung under a wing or built into the wing's leading edge. Small antenna size, however, limits operating range of these single-engine installations.

Lightning Detection

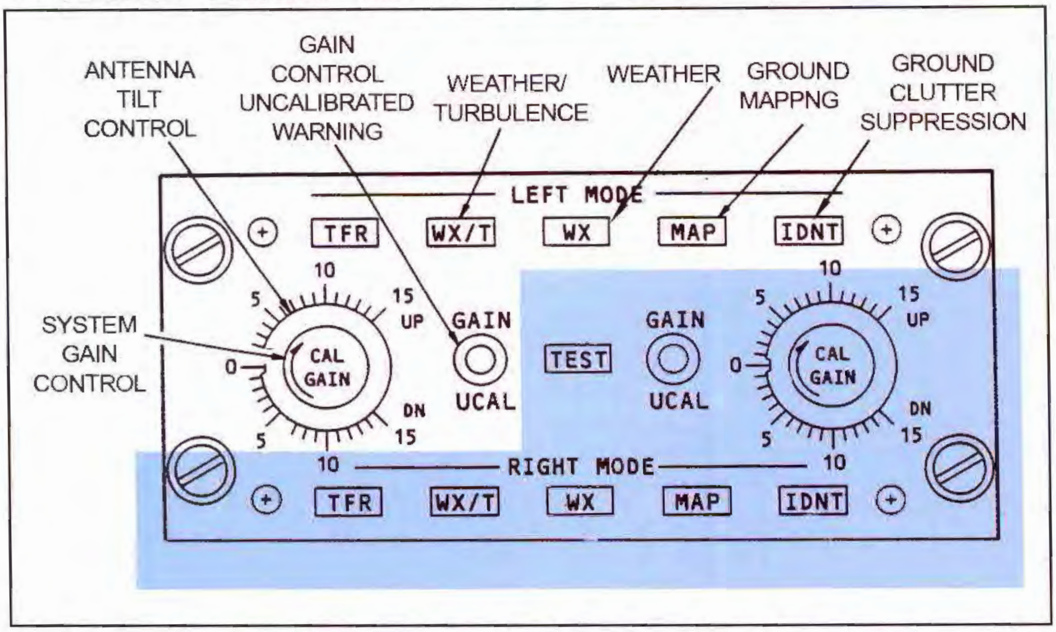
Weather research shows that thunderstorms create lightning in strong up and down drafts. Particles of dust, ice crystals and water rub against each other and build static electricity. When voltage rises sufficiently, an electrical discharge jumps between clouds (most of the time), while some charges move from cloud to earth. As heavy electrical currents heat and expand the air, they produce the sound of thunder---plus a wide spectrum of radio energy that travels hundreds of miles. You hear it as static on an AM radio during a storm. That energy is also an indicator of where turbulence is located.

Stormscope appeared in the 1970's as the first practical lightning detection system for aircraft. It became successful in single-engine airplanes because it doesn't need a radar antenna on the nose; just a small receiving antenna on the belly of the airplane.

The Stormscope is tuned to a region where radio energy of lightning is concentrated; the very low frequency of 50 kHz. The display is electronic which means there are no mechanically moving parts to lag behind, as in the case of an ADF needle.

The display also maps the storm. When a lightning stroke is sensed, a dot is placed on the screen that shows the direction and distance of the stroke. The dot is held on the screen and joined by the next dot. Storing these signals, therefore, builds a graphic image of thunderstorm cells and places them in the proper position relative to the nose of the airplane.

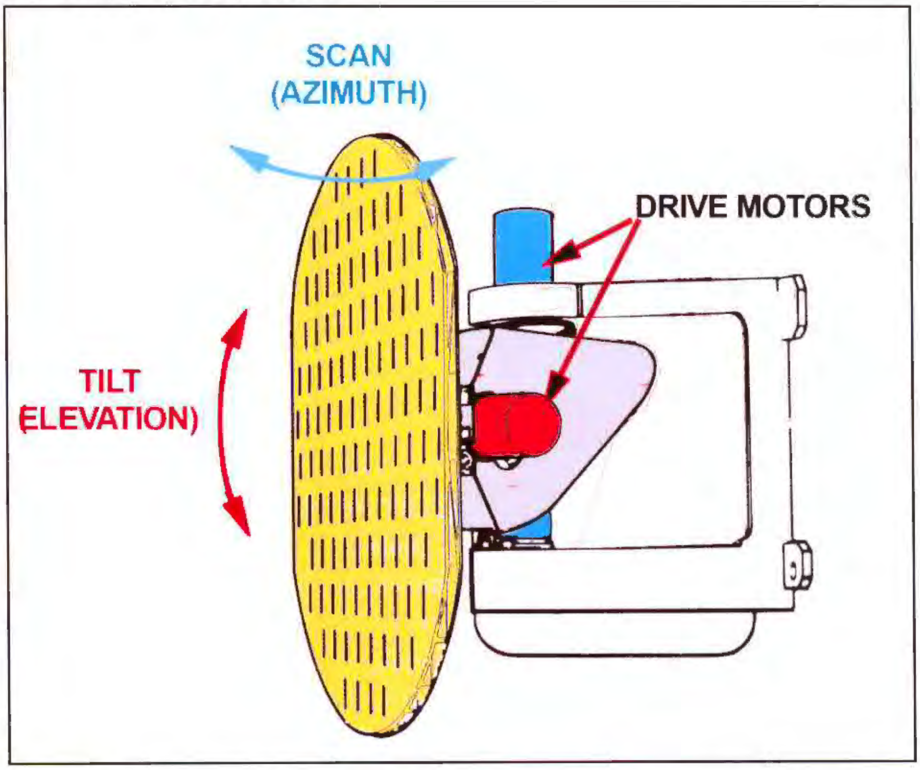
Weather Radar Control Panel



Both the captain and first officer operate the weather radar from the same control panel in this ARINC-type unit. Nearly all controls are duplicated; the captain's side is the white area, the co-pilot's is shown with a blue background. They are grouped as ""Left Mode" and "Right Mode" to indicate that the controls affect left and right sides of the instrument panel.

The panel, however, controls just one radar set and antenna. If captain and co-pilot choose different modes or ranges, they will see these selections on their displays. This is done by "time sharing" the radar scan. When the antenna swings from left to right, it obeys the captain's settings. When it scans from right to left, it reconfigures and responds to the co-pilot's switch settings. Thus, the two pilots may be viewing different weather situations on their displays---all from the same radar at nearly the same time.

Radar Antenna



Mounted in the nose of the aircraft, the weather radar antenna sends and receives up to about 300 miles. Scanning motion (side to side) covers an arc of about 120 degrees ahead of the aircraft. The tilt motor keeps the antenna pointed high enough to avoid receiving returns from the earth's surface and cluttering the display. If the antenna is tilted down for the mapping mode, the pilot sees large geographical features such as lakes and coastlines.

Early antennas followed the "dish" design (parabolic reflector), but later aircraft use the "flat plate" design shown above.

A little-understood function of the Stormscope is how it determines the distance to the storm. It's done by measuring the strength of the incoming signal and converting it to miles. This sounds plausible until the question arises; how does the Stormscope know if the storm is small and close by, or large and far away? Each condition would seem to produce the same strength.

Stormscope determines the difference because large storms don't produce more energy per stroke, but more strokes per second. The reason is, lightning is created when voltage between two air masses reaches a breakdown, or flashover, point. Let's assume a small cell discharges at 100 million volts and contains electrical energy of 500 megajoules. After the cloud charges again to 100 million volts, another stroke occurs. Next, consider a larger cell at the same distance. It also flashes over at 100 million volts and 500 megajoules of energy. The difference, however, is that a large cell has a greater source of energy (more area) and generates the next stroke in less time. Thus, all single strokes (from large and small cells) generate about the same amount radio energy. Using this reference, the Stormscope can determine the distance to any stroke by measuring its strength at the time of arrival.

Lightning detectors of this type are based on "sferics," derived from the world "atmospherics." They are not as accurate in range as weather radar and may show "radial spread," where dots appear closer than they actually are, especially during strong thunderstorm activity. Because the error makes a dot appear closer (and thus give an earlier warning) it is not considered a major flaw in the instrument.

Datalink

A recent addition to weather detection not only solves the single-engine radar problem but extends new services to aircraft of all sizes. It is datalink; sending weather images from National Weather Service radar sites to aircraft. The link is done via satellite and requires only a receiver and display.

The images are the same ones seen on TV weather broadcasts. The system is Nexrad (Next Generation Radar), a network of high-power ground radar stations. Because of their megawatt power and large antenna

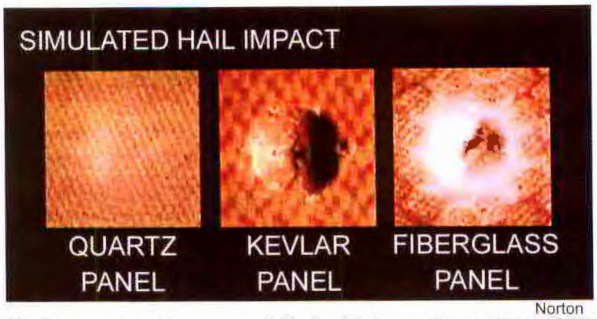
(continued page 144)

Radomes

The radome, which appears as a nose cone, protects the radar antenna from high speed impacts of rain, freezing moisture, hail and abrasive dust. Radomes must not only be structurally strong, but avoid reducing radar power by more than about 10 per cent. As the radome ages, it develops cracks and damage which eventually reduce the range and accuracy of the radar image. Frequent inspection and maintenance prevent this.

(Norton, and below)

Quartz radome used on the Airbus A-320.



Norton

Radomes erode, especially in high-performance aircraft. The test shown above illustrates a radome constructed of quartz, which has proven light and strong compared to other materials.

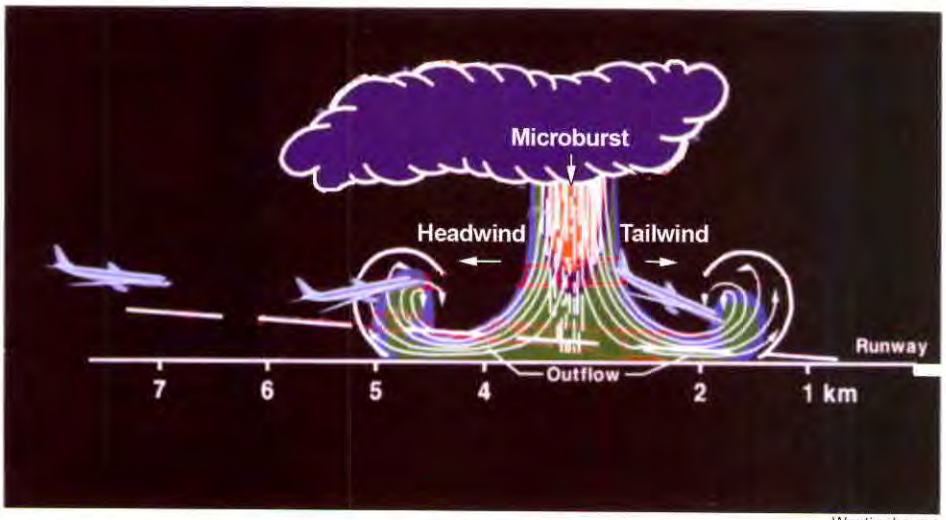
Radome Boot

3M

A pre-formed boot made of polyurethane may be applied over the radome for added protection. It reduces the effects of rain, snow, sleet, insects, sand and ultraviolet light

Radar antenna for a single-engine airplane cannot mount in the nose because of the propellor. Instead, it is located under the wing, as shown above, or built into the leading edge of wing.

Windshear



Westinghouse

Wind shear---a sudden change in wind direction or speed---is most hazardous when the aircraft is close to the ground, as during an approach. Windshear mostly affects pure jet aircraft because of slow turbine "spool-up" time; a delay of about 4 to 7 seconds after the pilot calls for full power.

The discovery of the "microburst" (pictured above) shows what happens. A small thunderstorm cell across the approach path is sending down a column of air from its core. As the wind strikes the ground it spreads in all directions. The airplane at the left is stabilized on the glideslope. When it reaches point "5" it enters a headwind at the edge of the microburst. This lifts the airplane above the glideslope, causing the pilot to reduce power or lower the nose to get back on. Next, the airplane reaches the strong downdraft from the center of the microburst and the airplane sinks further. The final phase is entering the tailwind portion of the microburst ("2"), causing further sinking and loss of performance. The complete windshear encounter may take less than a minute, hardly enough time to recover---and the airplane crashes short of the runway.

Because so many landing accidents were caused by windshear, protection systems are now required aboard airline aircraft. They not only give advance warning, but help the pilot fly the correct attitude for maximum climb out of the windshear condition.

Lightning Detection

L3 Communications

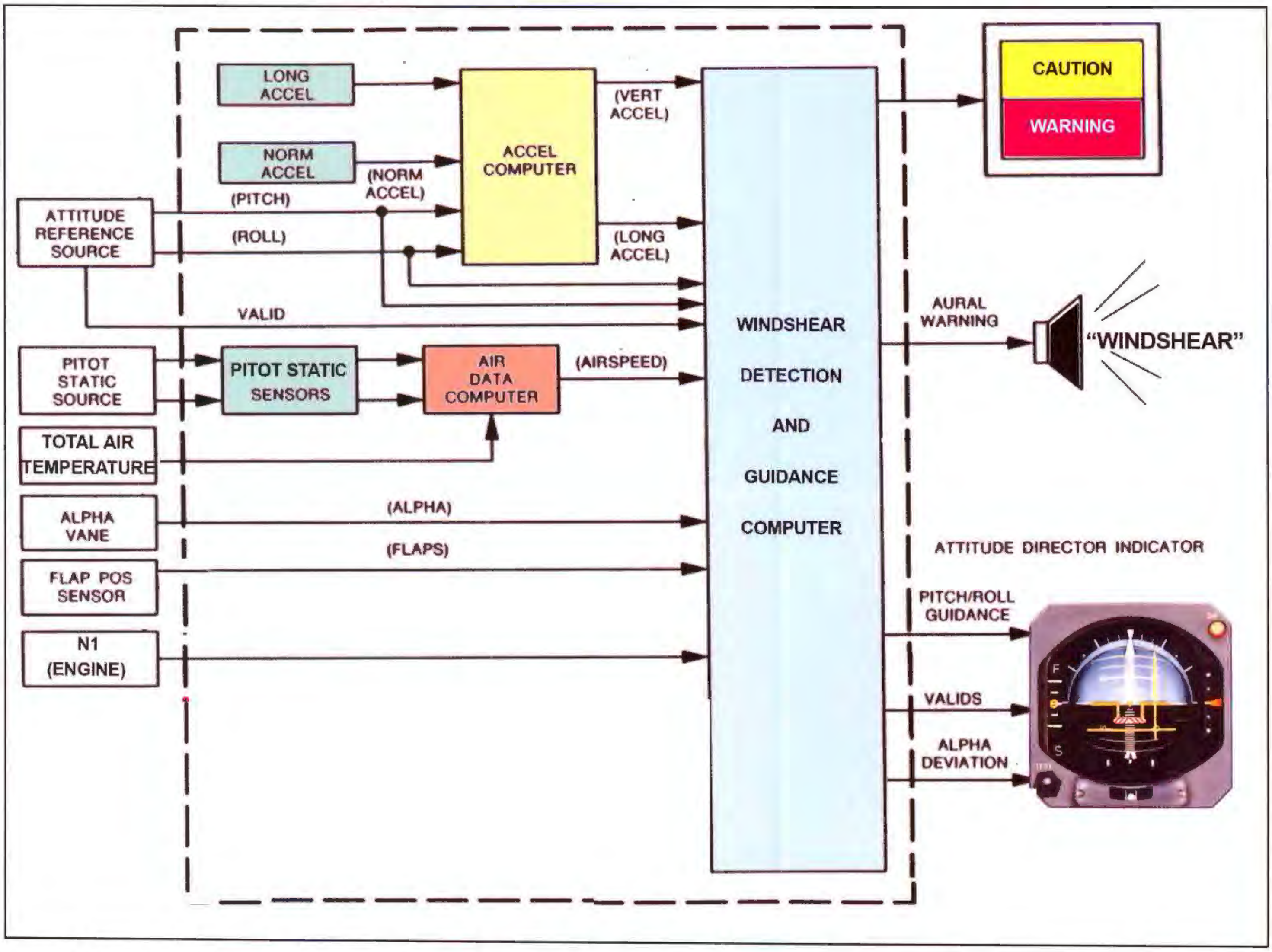
The Stormscope shows each lightning stroke as a green dot. The three large dot clusters are groups of thunderstorm cells. The display is 360 degrees, with the airplane in the center, thus showing activity behind the airplane. If the pilot wants to avoid storms ahead, he'll know not to make a 180-degree turn and fly into more storms.

If the Stormscope is connected to a magnetic heading source, it keeps the dots correctly oriented to the nose of the airplane. Without this connection, the pilot must manually clear the display after the airplane turns and await the buildup of more dots.

When there is little storm activity along the route, the pilot may choose the 200-mile range to see the "big picture." If dots start to appear, he shortens the range for greater accuracy; down to 100, 50 and 25 miles.

Because Stormscopes are sensitive to electrical discharges, the installation must be done carefully to avoid false dots due to strobe lights, magnetos and other electrical equipment.

Windshear Computer



The system detects windshear before the pilot sees it on his instruments or senses any danger.

The basic principle is to measure air speed, ground speed and inertial forces. If they start to differ at an excessive rate, it's caused by wind shear. For example, the pitot tube, which measures airspeed, is compared with an inertial sensor aboard the airplane which measures changes in acceleration of the airplane.

As seen in the diagram above, various sensors provide other information such as angle of attack (alpha) and temperature. Outside air temperature is also monitored because windshear is often accompanied by rapid temperature change.

Two alerts are developed: "Caution," which indicates the airplane is encountering a headwind and updraft. This is considered an increase in airplane performance. The second alert is "Warning," for a tailwind and downdraft (or a decrease in performance). Now the voice says "Windshear."

Guiding the pilot out of the windshear condition follows the warning. Without guidance, the pilot may simply add full power and raise the nose, which could stall the airplane. To avoid this, the windshear computer indicates the ideal flight path on the instruments (done by pitch cues on the attitude indicator).

dishes, they produce images of high quality. When severe weather is in an area, a Nexrad site repeatedly sweeps the sky for five minutes, mapping precipitation horizontally (for a conventional radar image) and sampling 14 different elevations (for a profile view), up to 140 miles away.

A feature unique of the Nexrad system is that a pilot may "look ahead" and see current weather any where in the country.

Lightning

The most hazardous weather to aircraft is turbulence in thunderstorm clouds. Turbulence also generates lightning (due to friction between particles), which may reach 100 million volts and 200,000 amperes. Detecting lightning is a good indication of turbulence. This information is available from ground stations or with a lightning detector aboard the aircraft. Radar, on the other hand, reads rainfall rate, also a good indicator of turbulence. The newest radars also measure turbulence by the horizontal motion of raindrops.

On average, an airliner is struck once a year by lightning, but with minor damage. Only one or two air crashes have ever been suspected of resulting from a lightning strike. Turbulence is the danger.

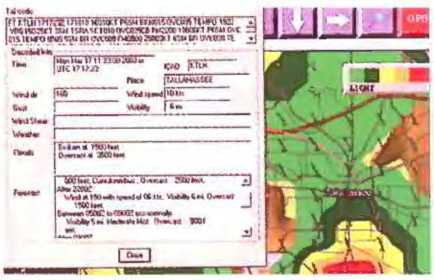
Datalink

Images and text are transmitted by datalink direct to the airplane from a geosynchronous satellite. The datalink service shown is by XM Satellite Radio.

Lightning strikes measured from the ground by the National Lightning Detection Network are updated every five minutes and sent to the aircraft by datalink.

Winds aloft are shown every 3000 feet up to 42,000 feet. Speed and direction are given.

METARS (aviation weather reports) are transmitted from the National Weather Service every 15 minutes.



TAFS (aviation forecasts) are also available from the National Weather Service.

Review Questions
Chapter 19 Weather Detection

19.1 What is the greatest threat of a thunderstorm to an aircraft?

19.2 On a weather radar display, what color indicates maximum hazard to an aircraft?

19.3 Weather radar detects storms by transmitting ________ of radio energy and measuring their echoes from water droplets.

19.4 Detecting turbulence in a storm is done by measuring echoes from the __________movement of water droplets.

19.5 What is the normal use of the tilt control?

19.6 What raises and lowers the radar antenna in a vertical direction for tilt control?

19.7 What causes the radar antenna to scan left and right (horizontal motion)?

19.8 How is the radar antenna stabilized as the airplane maneuvers through pitch and roll?

19.9 What is a typical frequency for an airborne weather radar?

19.10 Lightning detection systems are usually tuned to a frequency of _______.

19.11 What is the most recent method for delivering weather images to the cockpit?

19.12 What is the purpose of a radome?

19.13. Radomes must reduce radar power by no more than about ________.

19.14 Wind shear is a sudden change in wind ________ and is most dangerous near the________.

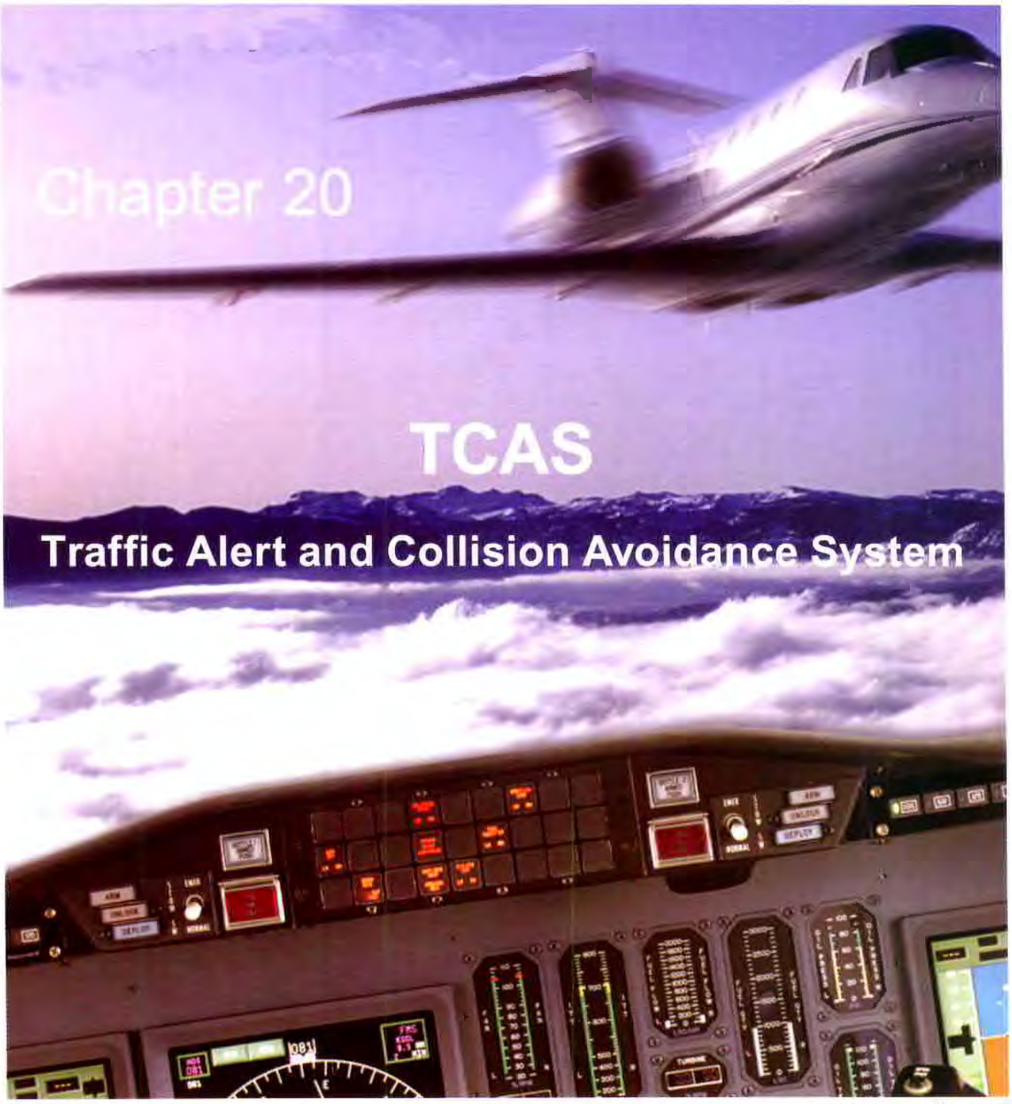
19.15 A dangerous form of windshear, which occurs over a small area, is known as a _________.

19.16 Windshear detection systems warn the pilot and also provide _____________.

Chapter 20

TCAS

Traffic Alert and Collision Avoidance System



Honeywell

Keeping aircraft safely separated had been the task of air traffic control since the 1930's when pilots radio'ed position reports by voice. This was followed primary surveillance based on radar "skin returns," then secondary surveillance using transponder interrogation and reply. But as airplanes began cruising near Mach 1 and air traffic multiplied, so did the threat of the "mid-air."

The search for a workable anti-collision system persisted for 50 years. Early experimental systems required costly atomic clocks, complex antennas and techniques borrowed from electronic warfare. Progress was slow until, in 1956, two airliners collided over the Grand Canyon on a sunny day. Closing at about 900 miles per hour, the pilots would have to see the other airplane at four miles, decide on the correct response, then maneuver off the collision course. All this would have to happen in 15 seconds. As a result of the accident, the U.S. Congress brought pressure on the FAA to develop an anti-collision system, and for airlines to install it at an early date.

During the 1960's, the transponder was spreading through aviation and researchers decided to abandon earlier technology and adopt the transponder as a building block in a new anti-collision system. After trying several variations, TCAS (Traffic Alert and Collision Avoidance System) was chosen as a world standard and it's now in widespread use everywhere, with scaled-down versions for business and light aircraft. In Europe the system is known as ACAS, for Airborne Collision Avoidance System, but all systems follow the standard adopted the International Civil Aviation Organization (ICAO).

While the transponder is a major component, the foundation is the TCAS processor. It performs one of the most intensive and rapid computations aboard the aircraft, executing software for collision logic. It must acquire, track and evaluate dozens of aircraft up to about 40 miles away---then issue commands on how to avoid a collision---all within seconds.

The road to TCAS was not entirely smooth. As

TCAS Symbols on a Radar Display

Bendix-King

If an airplane has an EFIS or radar display, it can show TCAS information. The weather radar control panel is at the top, with a button at top left for activating the TCAS display.

Besides TCAS symbols on the display, there are voice announcements. If a threat advisory (TA) appears on the display, the voice says, "Traffic, Traffic." If it turns into a resolution advisory (RA), the voice gives a command to climb or descend.

the first systems were fitted to aircraft, pilots complained about false alarms (and shut them off). It mostly happened near crowded terminals and at low altitude. The technical committee responsible for TCAS responded with software upgrades ("Changes") that address each complaint. The performance of TCAS is now so effective, the FAA ruled that if a pilot receives a clearance from a controller that conflicts with TCAS, the pilot must obey the TCAS. In 2002 a pilot ignored that procedure and caused a mid-air collision 35,000 feet over Europe between an airliner and a cargo plane. Air traffic control had instructed the pilot to descend, while TCAS advised him to climb. All 69 people perished in the collision. Both aircraft had fully functioning TCAS.

Basic Operation

Once every second, the transponder of a TCAS airplane automatically transmits an interrogation. This is similar to the interrogations sent out by air traffic surveillance radar and the frequencies are the same.

If another airplane is within range, its transponder replies to the interrogation. The first airplane measures the time between interrogation and reply to determine the distance (range) to the other aircraft. Also received is the altitude of the other aircraft, which is encoded in the transponder reply (mode C). If the other aircraft has a Mode S transponder, its address is also sent. Directional antennas aboard the interrogating airplane determine the bearing (direction) to the threat aircraft.

Because TCAS exchanges data between airplanes, it does not require ground stations. Thus, it can operate where there is no radar coverage, such as oceanic flight and over remote areas.

Once the TCAS processor acquires information about the other aircraft, it looks at the potential for a collision. A major factor is "range rate," which tells the rate at which distance is changing between the two aircraft. If that change is *constant*, the two aircraft are on a collision course. This is similar to what happens if a pilot looks out and sees another airplane that appears stationary in the sky. It means the two airplanes are converging. TCAS detects such threats long before they are visible to the pilot.

Tau

Airplanes differ greatly in speed and performance and TCAS must work with them all. This is done through a concept known as "tau" (the Greek letter) to adjust warnings to the actual situation. By measuring distance and closing rate to the target, TCAS might issue the first warning 40 seconds before a potential collision and a second one 25 seconds before. TCAS adjusts warning times according to aircraft speeds.

Vertlcal Speed Indicator Adapted for TCAS

Aircraft without electronic flight instruments (EFIS) may add a TCAS display by replacing the conventional VSI (vertical speed indicator) shown at the left.

The new instrument (right) still functions as a vertical speed indicator but adds TCAS symbols. In this example, the airplane (green symbol) is encountering a threat (red square) 6.5 miles ahead at 1 o'clock. The "+04" means the threat is 400 feet higher and remaining at that altitude

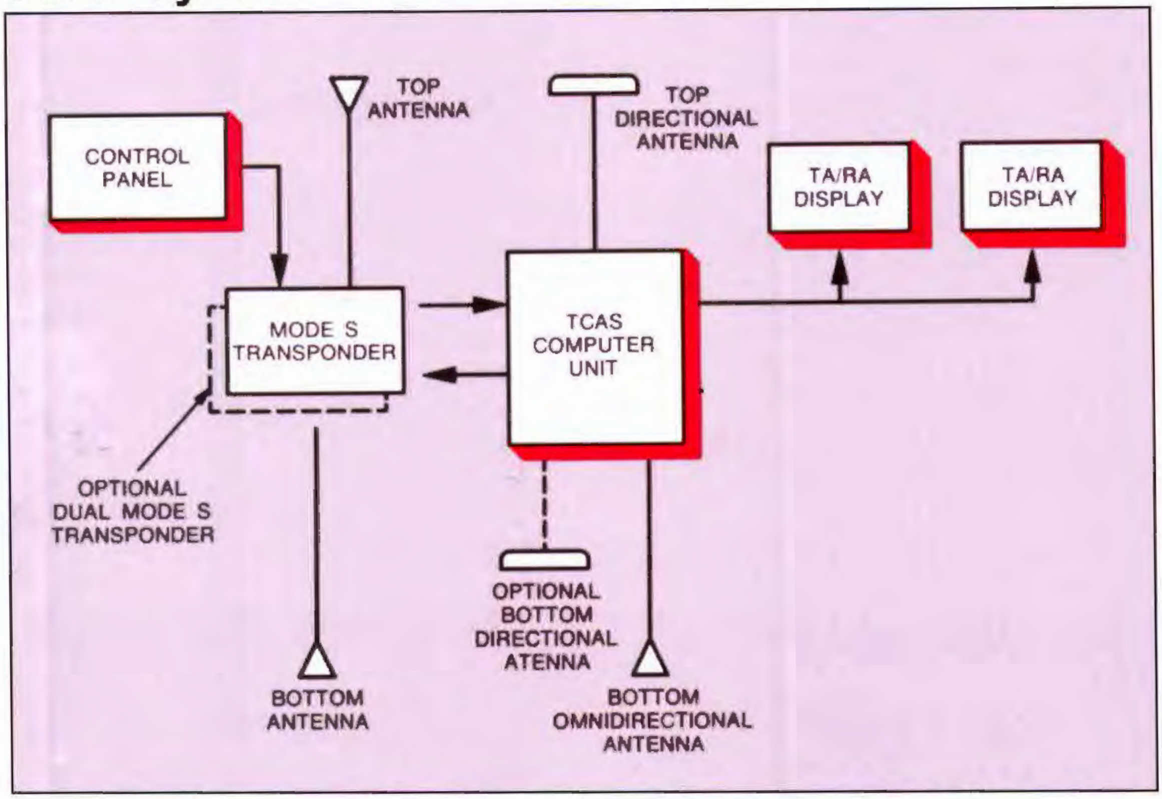
Because two airliners typically close at about 1000 nm/hour, they could be less than 30 seconds from a collision.

The TCAS system is issuing an "RA," or resolution advisory. This is a command for the pilot to make a rapid descent, as shown by the green area at lower right. The pilot is complying by flying toward that area, as shown by the vertical speed needle. The airplane is descending vertically about 3000 feet per minute.

Note the large circle of red around the instrument. It is warning the pilot not to climb or descend in this region, but to go for the green.

In this example, TCAS logic instructed the pilot to descend. Because TCAS in both aircraft are communicating by datalink, the other aircraft is commanded to climb. This is a "cooperative maneuver, " and produces maximum separation between aircraft.

TCAS System



Major functions of a TCAS II system. It requires a Mode S transponder to enable two closing aircraft to communicate and determine which direction to fly (up or down) to avoid a collision. The transponder often uses a top and bottom antenna on the aircraft to assure full coverage above and below. **The computer processes large amounts of information; transponder replies of other aircraft, target tracking, threat assessment, visual and aural advisories, escape maneuvers and coordinating maneuvers between closing aircraft.**

Traffic and Resolution Advisories

If a collision is possible, TCAS delivers two kinds of warnings:

•Threat Advisory (TA). This is the less serious of the two. It means another aircraft might be 45 seconds from the closest point of approach (CPA). The pilot sees the TA on a display (shown in the illustration) and becomes aware of the threat.

•Resolution Advisory (RA) With this warning the conflict is rapidly growing more serious. The threat aircraft could now be 30 seconds from closest point of approach. TCAS issues a Resolution Advisory, which commands the pilot to climb, descend, remain level or observe a vertical restriction, as shown.

TCAS I and TCAS II

There are two versions of TCAS, for large and small aircraft. The full system, TCAS II, is required aboard airliners and large transports with 31 or more seats. In TCAS II, the full collision logic is provided to generate the two types of warnings; TA (threat advisory) and RA (resolution advisory).

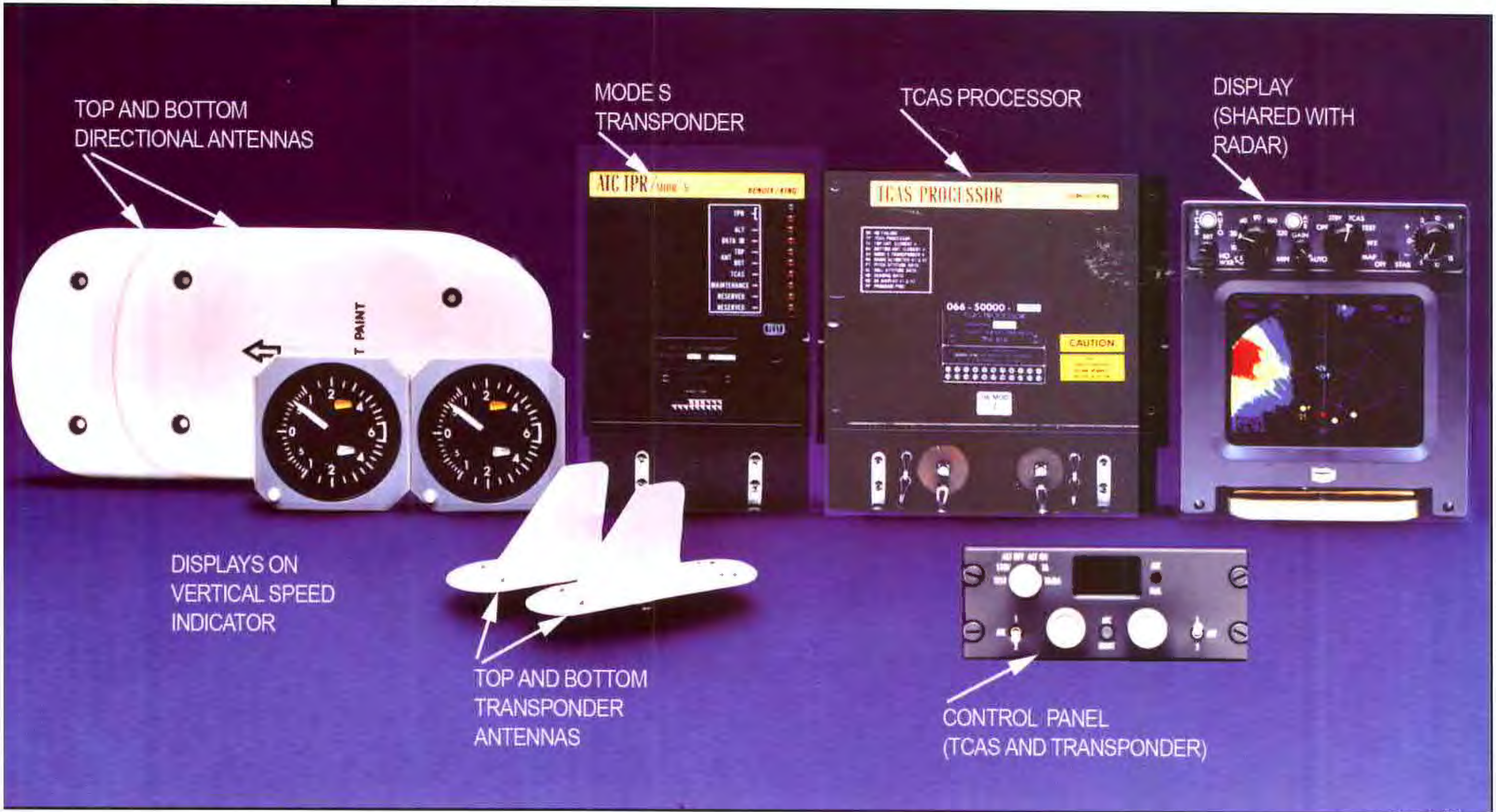
TCAS I is a scaled-down system that issues only TA's (threat advisories). Otherwise, everything is much the same as TCAS II; the symbols, warnings and displays. Lower in cost, TCAS I is designed for corporate, business and light aircraft.

The added complexity of TCAS II is in the collision logic for developing the evasive commands, a more elaborate antenna system, the need for a Mode S transponder and a method of air-to-air communication known as "datalink."

Coordinating Climb and Descend

When TCAS issues a Resolution Advisory (RA) it instructs the pilot how to avoid a collision by flying up or down. Obviously, if both aircraft fly toward each other and perform the same escape maneuver (both fly up, for example) they would collide. This is prevented by "coordination interrogations" transmitted by each aircraft once per second. These are regular transponder signals on 1030 and 1090 MHz, but now used as a datalink to exchange information between aircraft.

TCAS Components



Bendix-King

The control panel at lower right selects TCAS and transponder functions. Two antennas are used for the transponder---placed at top and bottom of the fuselage---to assure complete signal coverage around the airplane. Two directional antennas (left) also determine the bearing of a threat aircraft above and below the airplane.

Let's say the TCAS of one aircraft decides on a "fly up" maneuver. This is considered an *intention* and, in this example, is an "upward sense" (climb). The intention is transmitted to the other aircraft. This causes the TCAS of the second aircraft to select a "downward sense" (descend). Thus, when one aircraft receives the other's intention, it selects the opposite sense---so one flies up, the other flies down.

There is a possibility that both aircraft will see each other as a threat at the same instant and both select the same sense. If this happens TCAS logic goes to another source to break the conflict; the transponder address. (All Mode S transponders have a permanent address.) The aircraft with the *higher* address will reverse its sense.

Whisper-Shout

During the design of TCAS there was concern the system would overload because of too many replies, especially as airplanes converged on a busy airport. This was solved by the "whisper-shout" technique. As the airplane cruises, it transmits an interrogation at low transponder power, say 2 watts. Only the closest aircraft and those with the highest transponder sensitivity can hear it and reply. This is the "whisper"---which limits the replies to the closest airplanes. TCAS processes these replies, which are a small portion of the total number of targets.

Next, the transponder increases power slightly to trigger replies from aircraft slightly farther away. At the same time, however, the transponder also sends a "suppression" pulse which silences the first set of transponders and prevents their replies. In rapid steps, the interrogations increase in power, until they're "shouting" at 250 watts. These high-level signals now reach aircraft at the outer edge of coverage. It's important to note that each time the power ramps up it is followed by a suppression pulse that silences all transponders that replied earlier.

A complete whisper-shout cycle repeats once per second, effectively placing replies into small groups that are processed in sequence. This reduces clutter and overload.

Directional Interrogation

Besides whisper-shout, another technique reduces the number of replies received each second. The interrogations are transmitted through a directional antenna which electronically rotates 90 degrees at a time. This covers a full circle in four quadrants and limits replies to the active quadrant.

Non-TCAS Airplanes

The system can also recognize aircraft that are not carrying TCAS or Mode S transponders. Such aircraft typically have the earlier ATCRBS transponder. A TCAS-equipped aircraft, however, interrogates these aircraft and computes information required to display a threat advisory (TA). There can be no cooperative maneuvering because this requires Mode S transponders on both aircraft, as well as a TCAS system.

TCAS III

TCAS II commands the pilot only in the vertical direction, which is sufficient to avoid a collision. The industry had started work on TCAS III, to add commands in the horizontal direction (fly left, fly right) but it never was completed. The problems of issuing both vertical and horizontal maneuvers proved extremely difficult. Maneuvering in two dimensions simultaneously multiplies the chances for aircraft to create new collision courses with second and third airplanes as they avoid the first one. Before these problems were solved, TCAS III was abandoned as new systems began to examine the collision threat.

A new global air traffic system is emerging with collision avoidance based on GPS and satellites. It is ADS-B---automatic dependent surveillance-broadcast. As aircraft cruise they "squitter" (automatically transmit) their position based on GPS. That information is picked up by nearby aircraft for collision avoidance and also relayed via satellite to air traffic control for managing traffic.

Yet another system began during 2004. Known as TIS, Traffic Information Service, it broadcasts the targets shown on all surveillance radars on the ground. The images are downlinked via satellite to aircraft, which display traffic, as done with TCAS.

TCAS, however, will be operational for many generations. It is still unequalled as the tactical collision avoidance system anywhere on earth.

TCAS Voice Warnings

1. Traffic Advisory (TA): "TRAFFIC, TRAFFIC"

2. Resolution Advisories (RA):

Preventive:

"MONITOR VERTICAL SPEED, MONITOR VERTICAL SPEED"

The pilot keeps the VSI needle out of the lighted segments.

Corrective:

"CLIMB, CLIMB, CLIMB"

Climb at the rate shown on the RA indicator; nominally 1500 fpm.

"CLIMB, CROSSING CLIMB, CLIMB, CROSSING CLIMB".

As above, except that it further indicates that own flight path will cross through that of the threat.

"DESCEND, DESCEND, DESCEND".

Descend at the rate shown on the RA indicator; nominally 1500 fpm.

"DESCEND, CROSSING DESCEND, DESCEND, CROSSING DESCEND"

As above except that it further indicates that own flight path will cross through that of the threat.

"REDUCE CLIMB, REDUCE CLIMB"

Reduce vertical speed to that shown on the RA indicator.

"REDUCE DESCENT, REDUCE DESCENT"

Reduce vertical speed to that shown on the RA indicator.

"INCREASE CLIMB INCREASE CLIMB"

Follows a "Climb" advisory. The vertical speed of the climb should be increased to that shown on the RA indicator, nominally 2500 fpm.

"INCREASE DESCENT, INCREASE DESCENT"

Follows a "Descend" advisory. The vertical speed of the descent should be increased to that shown on the RA indicator, nominally 2500 fpm.

"CLIMB, CLIMB NOW, CLIMB, CLIMB NOW".

Follows a "Descend" advisory when it has been determined that a reversal of vertical speed is needed to provide adequate separation.

"DESCEND, DESCEND NOW DESCEND, DESCEND NOW"

Follows a "Climb" advisory when it has been determined that a reversal of vertical speed is needed to provide adequate separation.

Review Questions
Chapter 20 TCAS (Traffic Alert and Collision Avoidance System)

20.1 A TCAS aircraft transmits an interrogation once per ______.

20.2 How does an intruder aircraft with an ATCRBS (early type) transponder reply to TCAS interrogations?

20.3 How does an intruder aircraft with a Mode S transponder reply to TCAS interrogations?

20.4 How does TCAS determine the direction of a threat?

20.5 How does TCAS determine the distance of a threat?

20.6 How does TCAS determine whether the other aircraft is a threat?

20.7 What is the concept of "Tau".

20.8 Name the two kinds of warnings issued by TCAS.

20.9 Does a Threat Advisory (TA) command the pilot to maneuver out of the way?

20.10 What does an Resolution Authority (RA) do?

20.11 If two TCAS aircraft are closing, what prevents them from climbing, and flying into each other?

20.12 What is the technique of "whisper-shout"?

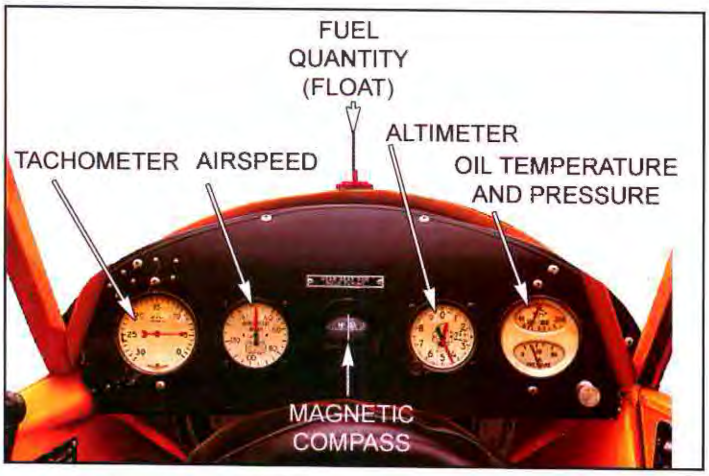
20.13 How does the directional antenna reduce the number of replies for each interrogation?

Chapter 21

Planning the Installation

Installations vary, from wiring a headset jack to rebuilding an instrument panel. No matter how extensive, it must follow rules of "airworthiness"---guidance by a civil aviation authority such the FAA in the US or a CAA in other countries.

Observe the TC. For major rebuilding of an instrument panel, there is an overriding rule about where you can place equipment. *Certified* airplanes---those built in a factory and sold ready to fly---must obtain a TC, or Type Certificate. The TC shows all equipment delivered with the airplane. Such equipment may not be moved to other locations on the panel without violating the TC. They may be replaced with equivalent units, but not shifted around. This does not prevent adding new equipment to the panel, or minor relocation of radios in a center stack, for example. These alterations will be noted on forms submitted for approval to the government agency.



Instrument panel of the original Piper Cub, which received its Type Certificate in 1931. Today, the same instruments are still required for "day VFR" flying. More airplanes, however, show the same information on an electronic display, as seen on the next page.

The pilot/owner handbook or flight manual typically lists the equipment installed under the Type Certificate.

STC. When adding systems to a factory-built airplane, using equipment critical to flight, this is usually done under an STC, or *Supplemental Type Certificate*. The manufacturer of the new system proved its airworthiness to obtain the STC. Examples include autopilots, displays and fuel management systems. For such installation, you will work from drawings prepared by the STC-holder showing precisely where and how components mount.

STC's can be compared to a patent; they are owned exclusively by the designer and protected by law. Often, the STC is offered for sale to avionics shops, along with the system and an installation kit. In cases where a manufacturer is selling a major system, such as an autopilot, he often allows the buyer to use the STC at no extra cost.

For large aircraft, expect more support from the avionics manufacturer. If a fleet of 30 air transports will be upgraded with a collision avoidance system, chances are a field representative from the manufacturer will assist in early installations.

Non-certified airplanes. There is a wide range of aircraft operating in the "Experimental" category, which includes kit-built, built-from-plans, antiques, warbirds

One EFIS Screen Replaces Ten "Steam Gauges"

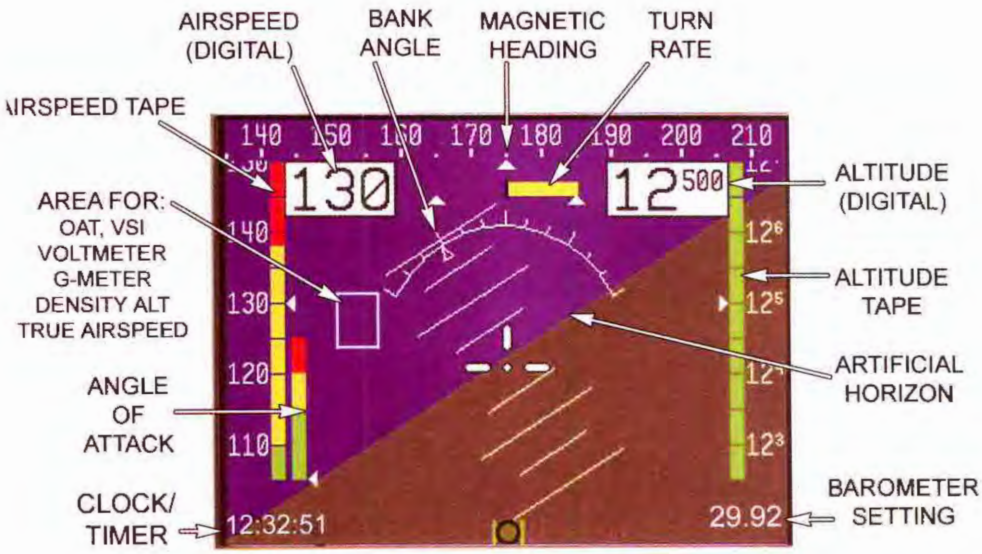
Tachometer from a 1931 Piper Cub is a 3-inch instrument that shows one function: RPM.

The future of instrument panels is EFIS (Electronic Flight Instrument System). In this comparison, the Piper Cub tachometer is only slightly smaller than the EFIS screen below, which displays ten or more instruments.

Nevertheless, the technician will see "steam gauge" instruments for generations to come. It will take that long for over 100,000 airplanes in the U.S. alone to fully change over to the new technology.

The Dynon system below is the first of the simple, low-cost EFIS screens. As this and other systems gain certification for production aircraft, they will gradually be installed as an upgrade to existing instrument panels. By 2005 nearly all airframe manufacturers announced they will install EFIS in their new airplanes.

The airlines have been flying with EFIS since 1982, beginning with the Boeing 757 and 767. They use cathode ray (TV) tubes, while new EFIS has flat-panel LCD displays.



This Dynon 4-inch EFIS screen is only slightly larger than the Piper Cub tachometer above.

and space vehicles. If they are registered as experimental, the avionics installation does not have to follow the same rules of certified aircraft. Instrument and radio placement may be designed by the builder. Many kit-built aircraft are capable of speeds greater than production aircraft, fly at higher altitudes and with such advanced systems as integrated displays, pressurization and turboprop powerplants. For safety's sake, these installations should also follow recommendations for airworthiness that apply to certified airplanes. Experimenters are encouraged (the Wright brothers began as bicycle mechanics), but home-built aircraft are inspected and an FAA representative may not accept something which appears unsafe.

Type of Flying

An airplane is typically outfitted according to type of flying, which informally divides as follows:

Day VFR. The airplane flies during daylight hours and under VFR (visual flight rules). Besides required instruments (see table) the pilot may want nothing more than a handie-talkie for communication and a portable GPS for navigation. This is often a solution when the airplane has no electrical system (battery and generator).

Night VFR. Even on clear, moonlit nights, flight after sundown should have avionics redundancy; a second com and second means of navigation. Flying VFR after dark is not only ruled out in every country outside the U.S., but the accident rate is ten times higher on dark, moonless nights. The pilot should be able to call for help if he inadvertently flies into a cloud at night or is lost with no backup navigation.

Light IFR. Many pilots obtain a rating to fly under IFR (instrument flight rules), but rarely use it. But it is a great timesaver when the obstacle is a low cloud layer only in the vicinity of the airport. The IFR rating is used only to fly for the few minutes it takes to climb above, or descend through, thin layers.

Low IFR. This is for the serious pilot who needs to get through widespread areas of low visibility, then shoot an instrument landing to a runway under a low ceiling. This aircraft needs reliable, redundant avionics. Safety will greatly improve with a terrain avoidance advisory system, weather detection and a satellite datalink that delivers the images of Nexrad, the ground weather radar network. Although not a requirement for private pilots, an autopilot is essential to safe single-pilot IFR operations.

Aircraft, flying under any condition---day, night or on instruments---benefit from some type of collision avoidance. The chance of a mid-air is the opposite of what is generally believed. Virtually no collisions occur inside clouds or at night. Most happen on a bright VFR day in the vicinity of an airport when airplanes converge for landing. As the chapter on collision avoidance describes, there are anti-collision systems to fit any size airplane.

Instruments and Radios

Applies to powered civil aircraft with a standard airworthiness certificate operating under FAA Part 91 (mainly private and corporate aircraft). For more specific requirements, and air transport requirements, check Federal Air Regulations.

Day VFR

1. Airspeed
2. Altimeter
3. Magnetic direction indicator (compass)
4. Tachometer for each engine
5. Oil pressure gauge for each engine using pressure system.
6. Temperature gauge for each liquid-cooled engine.
7. Oil temperature gauge for each air-cooled engine.
8. Manifold pressure gauge for each altitude engine (usually applies to aircraft with controllable pitch propellers).
9. Fuel gauge showing quantity in each tank.
10. Landing gear position indicator (
11. Anti-collision light
12. Emergency locator transmitter (ELT)
13. Transponder, with Mode A and C (when operating in high-traffic areas and within 30 miles of large airports.

Night VFR

1. All instruments for day VFR.
2. Position lights
3. Anti-collision light
4. Landing light (if operating for hire)
5. Adequate source of electrical energy for electrical and radio equipment.
6. Spare set of fuses or three spare fuses of each kind required, available to pilot in flight.

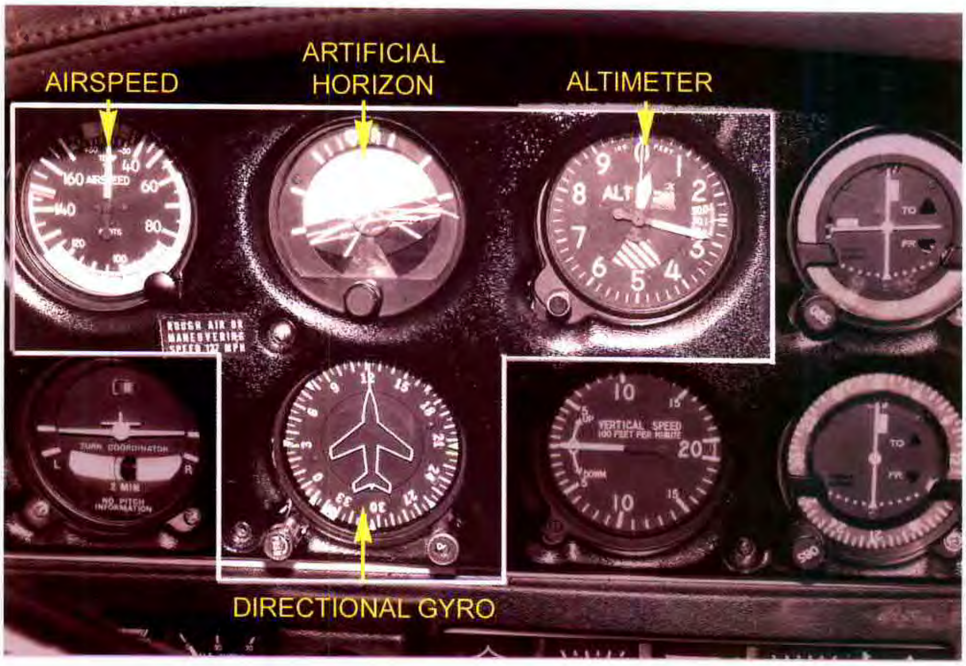
Instrument Flight Rules (IFR)

1. All instruments for day and night VFR
2. Two-way radio and navigation equipment appropriate to the ground facilities used.
3. Gyroscope rate of turn indicator (except where aircraft has a third attitude instrument.
4. Slip-skid indicator
5. Sensitive altimeter with setting for barometric pressure.
6. Clock with hours, minutes, seconds with sweep-second pointer or digital display.
7. Artificial horizon (gyroscopic pitch and bank)
8. Directional gyro
9. Flight at or above 24,000 ft MSL. If VOR navigation is used, DME is required.

Other Requirements

1. Altitude alerting system for turbojets
2. Large and turbine-powered multiengine air planes: flying over water (more than 30 min utes' flying time or 100 nautical miles from shore).
   - Two transmitters
   - Two microphones
   - Two headsets or one headset and one speaker
   - Two independent receivers
   - Two independent electronic navigation units (appropriate to the air space flown)
   - HF communications, if necessary to the flight.

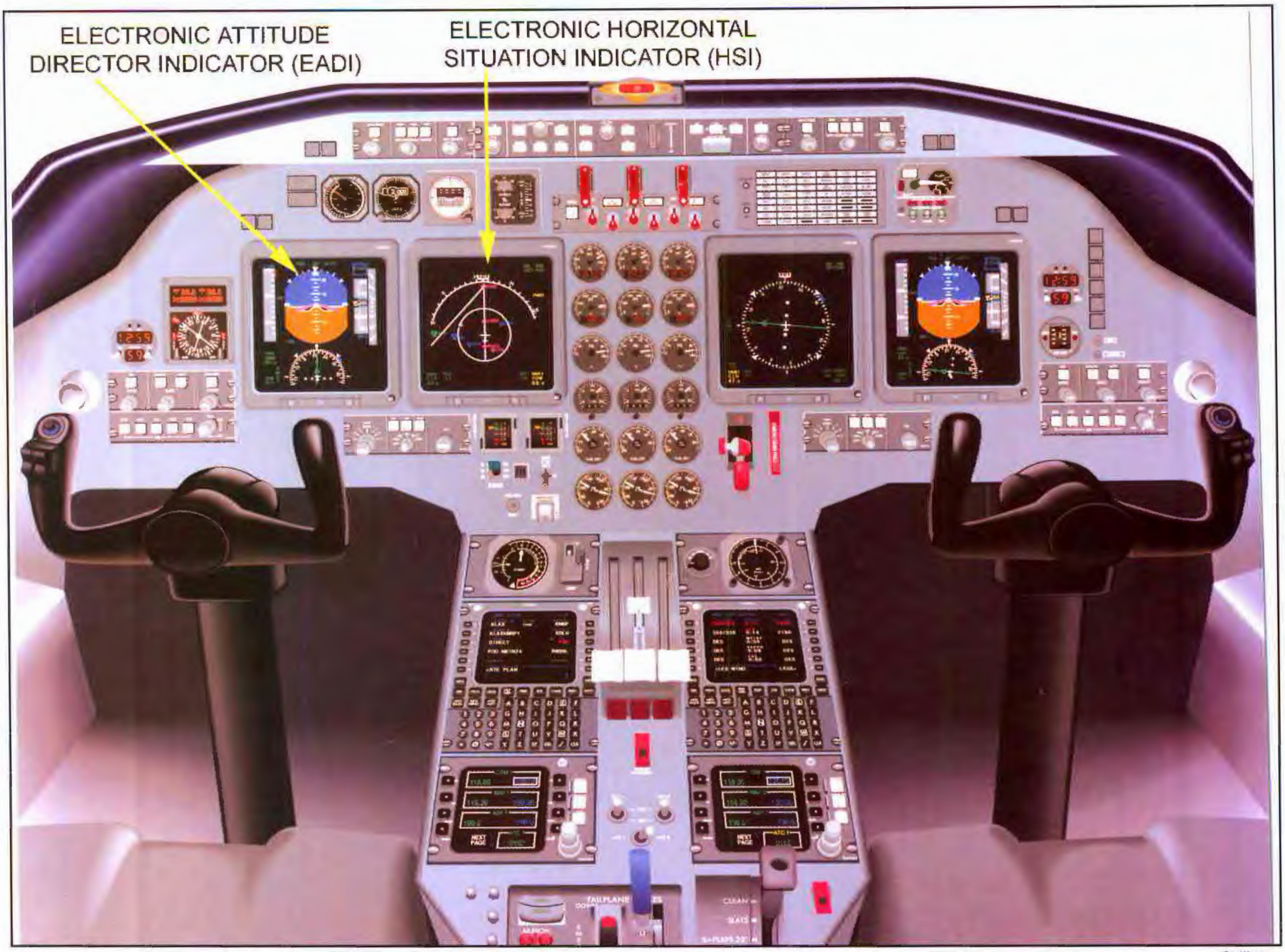
Basic T Instrument Layout



Most light aircraft---Cessna, Piper and Mooney, for example, add the two lower instruments to the basic T; the turn coordinator and vertical speed indicator. This equips the airplane for basic instrument flying. Some technicians call this the "six pack."

Large Aircraft

Turbine-powered airplanes are often outfitted with a "suite" of avionics from one manufacturer, as in this EFIS system.



Collins

An early EFIS system, introduced in the mid-1990's, is still flying aboard many business aircraft and regional airlines. It has four cathode ray tubes in the instrument panel, with two more tubes down in the pedestal. Pilot and co-pilot sides are nearly identical. The tube at the left, the Electronic Attitude Director Indicator, is mainly for flying the airplane manually or on autopilot. It also contains radionavigation information. Second tube from the left is the Electronic Horizontal Situation Indicator, which displays compass, waypoint, weather radar and other information The two tubes below, in the pedestal, are for flight management---mostly to store and fly routes, waypoints and airports---loaded on the ground before take-off. Shown here is a Collins Pro Line for the Falcon 50 .

Flat Panel, Integrated EFIS

Cirrus

By the year 2000, the future of instrument panels was clear. Flat panels (LCD's) would replace cathode ray tubes (CRT's). Instruments would become "integrated," that is, separate gauges merge into the electronic display.

The main part of the display shown here are two 10.4-inch (diagonal) flat panel LCD's The one at top left is the PFD, or "Primary Flight Display." Although it can depict almost any information, it is often used as shown; the top half for flying attitude, the lower half with compass and waypoint information.

The display on the right is the MFD, or "Multifunction Display," which shows moving map, traffic, weather and other data. The three small round instruments on the lower left are for backup---airspeed, attitude and altitude---but they are electronic, not electromechanical, displays. Over on the far right are engine instruments. The trend, however, is to merge these onto the main electronic displays.

This airplane, the Cirrus SR-22, eliminates the vacuum system usually required in production airplanes. Regulations require that flight-critical instruments have different power sources; usually accomplished with an electric-driven turn coordinator and a vacuum-driven artificial horizon. The all-electric Cirrus satisfies the rules by having two batteries and two alternators.

The EFIS system is the FlightMax Integra by Avidyne.

Typical Avionics Equippage

The instrument and radio chart shown earlier covers only equipment required by law. Aircraft owners often add systems to reduce workload or improve safety.

DAY VFR
- COM
- PORTABLE GPS (or GPS/COM)
- TRANSPONDER
- ALTITUDE ENCODER
- INTERCOM

BASIC IFR
- AUDIO PANEL, 3-LIGHT MB AND INTERCOM
- #1 GPS/COM (VFR)
- #2 NAV/COM
- VOR/LOC INDICATOR
- TRANSPONDER
- ALTITUDE ENCODER
- ADF

IFR
- AUDIO PANEL, 3 LIGHT MB AND INTERCOM
- MOVING MAP/GPS (VFR)
- NAV/COM
- VOR/LOC/GLIDESLOPE INDICATOR
- GLIDESLOPE RECEIVER
- TRANSPONDER
- ALTITUDE ENCODER
- AUTOPILOT, 1 AXIS (RADIO TRACK, HEADNG)
- ENGINE MONITOR
- ADF

FREQUENT IFR
- AUDIO PANEL 3-LIGHT MB, INTERCOM
- MULTIFUNCTION DISPLAY / MOVING MAP
- COM
- GPS (IFR)
- NAV/COM
- HSI WITH SLAVED COMPASS SYSTEM
- VOR/LOC/GLIDESLOPE INDICATOR
- GLIDESLOPE RECEIVER
- TRANSPONDER
- ALTITUDE ENCODER
- AUTOPILOT, 2 AXIS (TRK, HEADNG, ALT HOLD)
- ENGINE MONITOR
- STORMSCOPE AND/OR NEXRAD WX UPLINK
- FLIGHT TELEPHONE
- ENTERTAINMENT SYSTEM
- ADF

CORPORATE AIRCRAFT
- AUDIO PANEL, 3-LIGHT MB, INTERCOM
- MULTIFUNCTION DISPLAY / MOVINGMAP
- WEATHER RADAR
- GPS (IFR)
- NAV/COM #1
- NAV/COM #2
- HSI WITH SLAVED COMPASS SYSTEM
- VOR/LOC/GLIDESLOPE INDICATOR
- GLIDESLOPE RECEIVER
- TRANSPONDER #1
- TRANSPONDER #2
- ALT ENCODER #1
- ALT ENCODER #2
- AUTOPILOT, 2 AXIS (TRCK, HEADING, ALT HOLD)
- ENGINE MONITOR
- STORMSCOPE
- FLIGHT TELEPHONE
- COLLISION AVOIDANCE
- TERRAIN AVOIDANCE
- IN-FLIGHT ENTERTAINMENT
- ADF

TURBINE AIRCRAFT
- AUDIO PANEL, 3-LIGHT MB, INTERCOM
- MULTIFUNCTION DISPLAY / MOVING MAP
- RADAR INTERFACED TO MFD
- GPS (IFR)
- NAV/COM #1 NAV/COM #2
- VOR/LOC/GLIDESLOPE INDICATOR
- GLIDESLOPE RECEIVER
- TRANSPONDER #1, TRANSPONDER #2
- ALTITUDE ENCODER #1 and #2
- HSI WITH COUPLED COMPASS SYSTEM
- FLIGHT DIRECTOR
- AUTOPILOT, 3 AXIS WITH YAW DAMPER
- ENGINE MONITOR
- STORMSCOPE INTERFACED TO MFD
- SATPHONE OR FLIGHT TELEPHONE
- COLLISION AVOIDANCE
- TAWS: TERRAIN AVOIDANCE
- IN-FLIGHT ENTERTAINMENT SYSTEM
- EFIS OPTIONAL
- ADF
- HF FOR TRANS-OCEANIC AIRCRAFT

Manuals and Diagrams

The key to an installation is the manufacturer's manual on the specific model. Besides showing where each wire connects, pictorial drawings clarify difficult areas and give dimensions, power consumption and mounting hardware. There are schematic diagrams for troubleshooting.

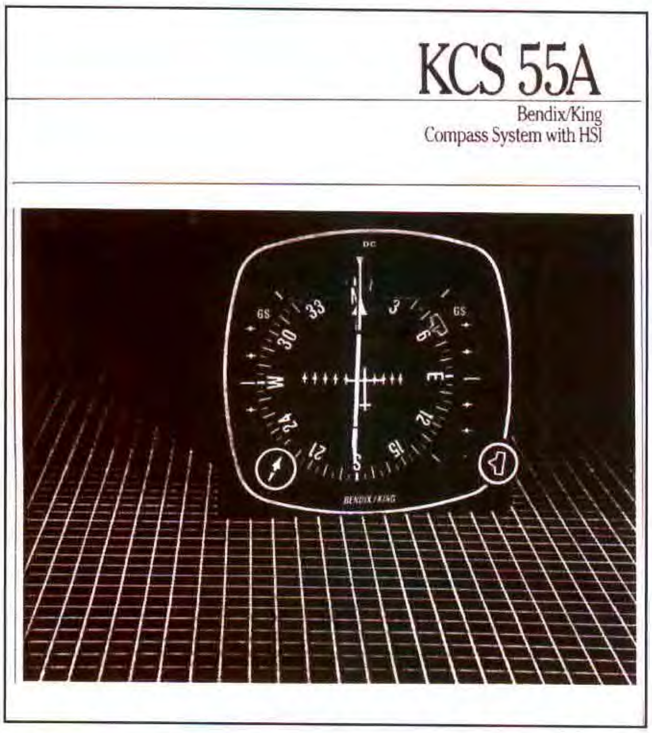
A manufacturer's manual is also accepted by a government inspector (FAA, CAA) as "approved data." At some future time you may be questioned on what you used for installation guidance---and you can point to the manual.

There is no special format for manuals in General Aviation. In the airlines, however, manuals are written according to an ATA (Air Transport Association) "chapter." These documents include the "Component Maintenance Manual" and "Illustrated Parts Catalog."

The section in the manual used much of the time is the "pin-out diagram," which shows how wires run among various connectors and units during an installation. It's also used for troubleshooting later on.

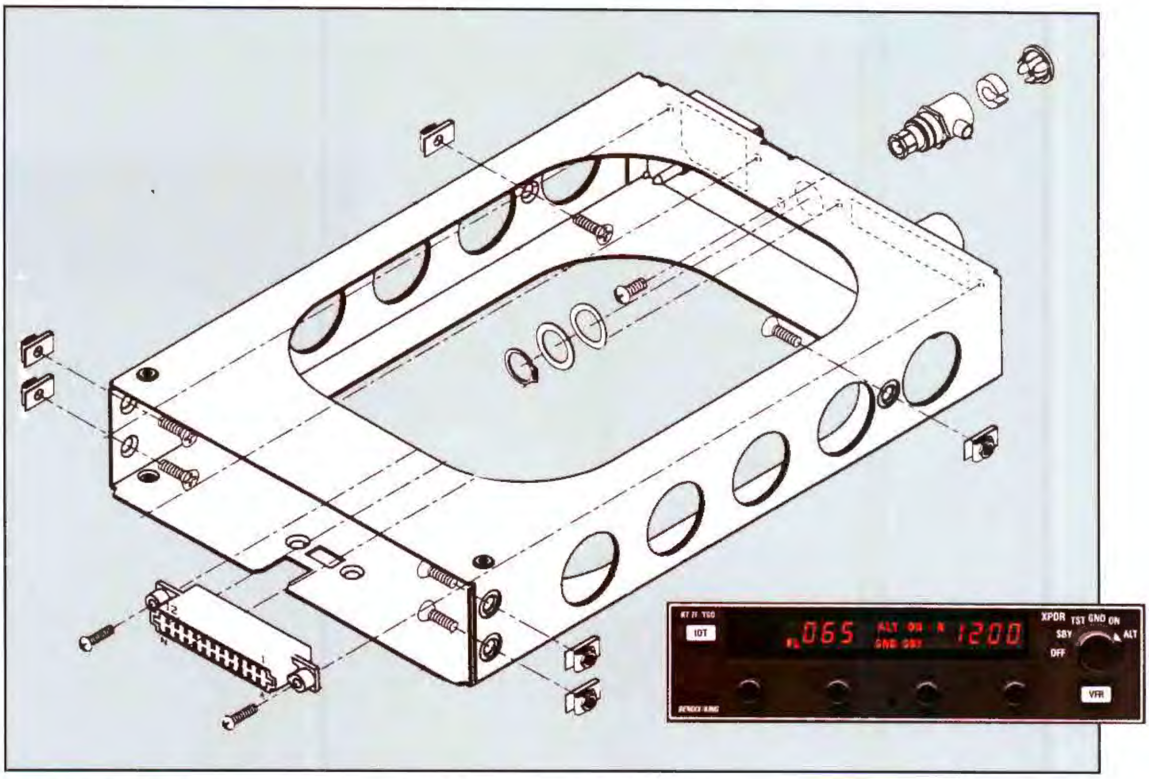
Obtaining Manuals

There are several sources for installation manuals. If a maintenance shop is a dealer for an avionics manufacturer, it's usually required to have a library of



Typical manufacturer's manual for General Aviation, in this illustration a Bendix-King compass system with a horizontal situation indicator. Always check the model number on the unit and compare it with the manual. For example, the model name "KCS 55A" may not be the same as "KC 55," although the illustration may appear the same.

Installation Drawing



Pictorial illustrations in a manual, like this one for a Bendix-King transponder tray, are essential for mounting hardware. The drawing shows where to assemble connectors and gives details on fastening the tray to the instrument panel.

manuals for the equipment it installs. These books are purchased directly from the manufacturer.

Manuals are also available to members of "Resource One." This is an on-line service of the Aircraft Electronics Association (www.aea.net).

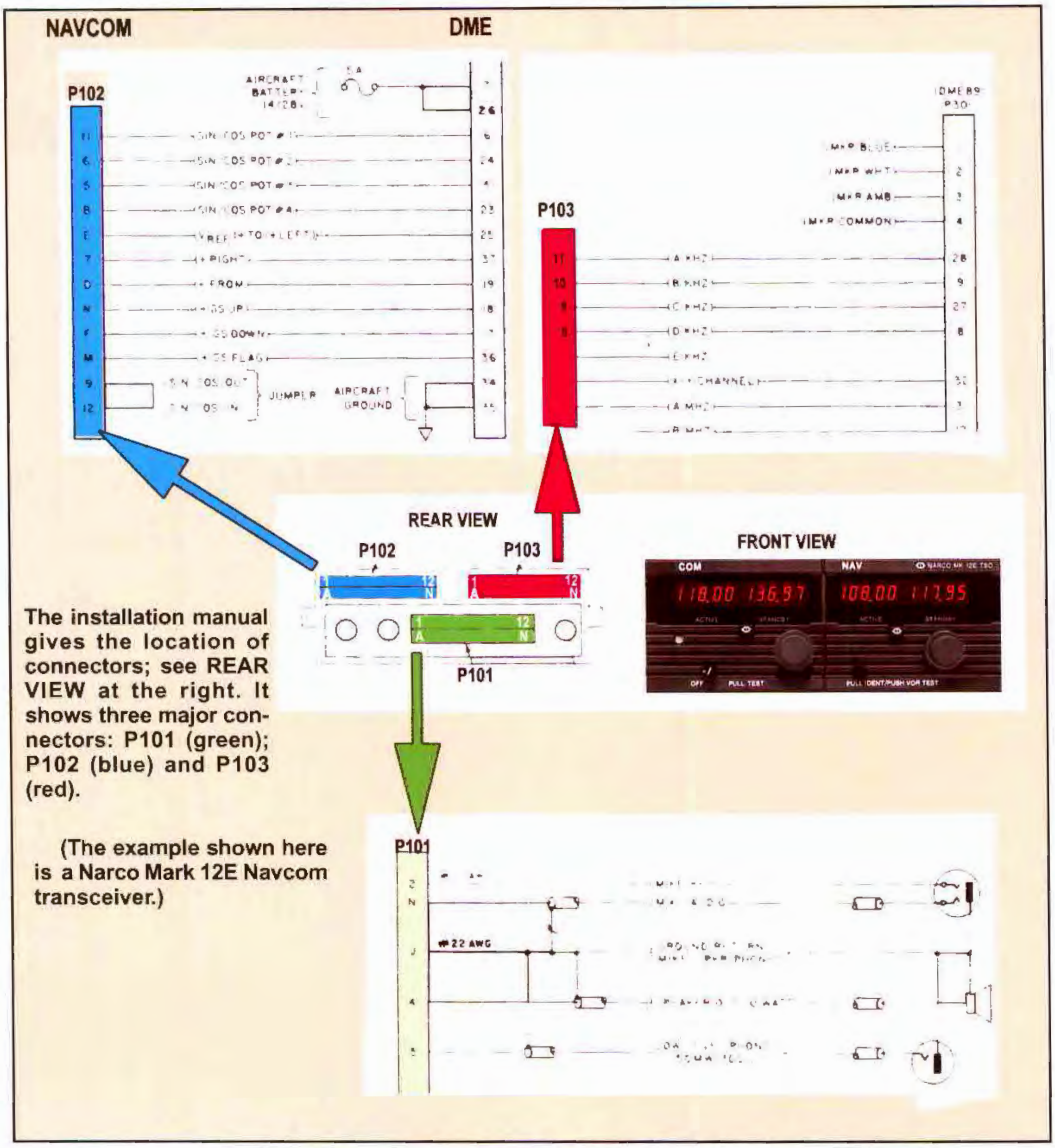
Manuals are sometimes available from resellers who list them in aviation publications.

In some instances, manufacturers make their manuals available on line at no charge.

Schematic (Circuit) Diagrams

Manuals contain schematics for troubleshooting down to the circuit board level and are not often required for installation work. An installer follows pin-out or interface diagrams like the examples shown on these pages. The schematic shows every resistor, capacitor, chip and other small component soldered to printed circuits inside the radio enclosure. The schematic is more useful for troubleshooting on the shop bench with specialized test equipment.

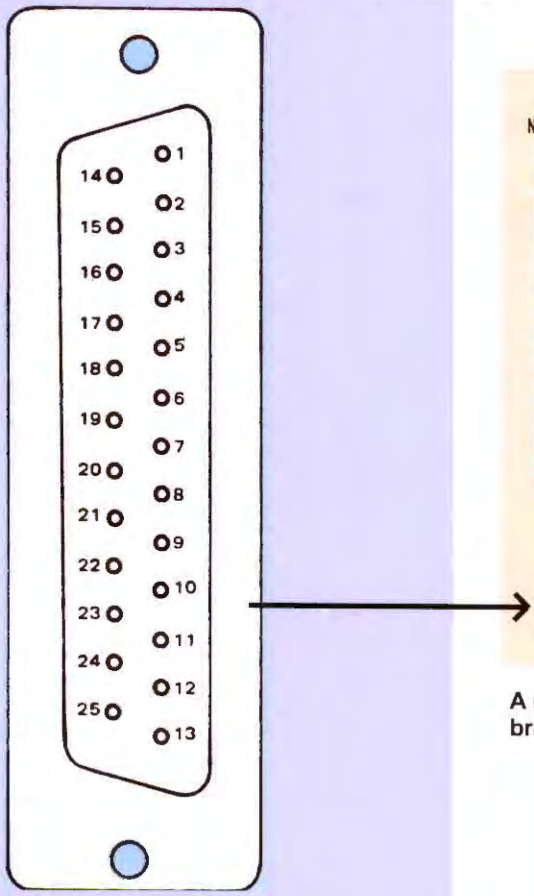
The Manual Locates Connectors and Pin Numbers



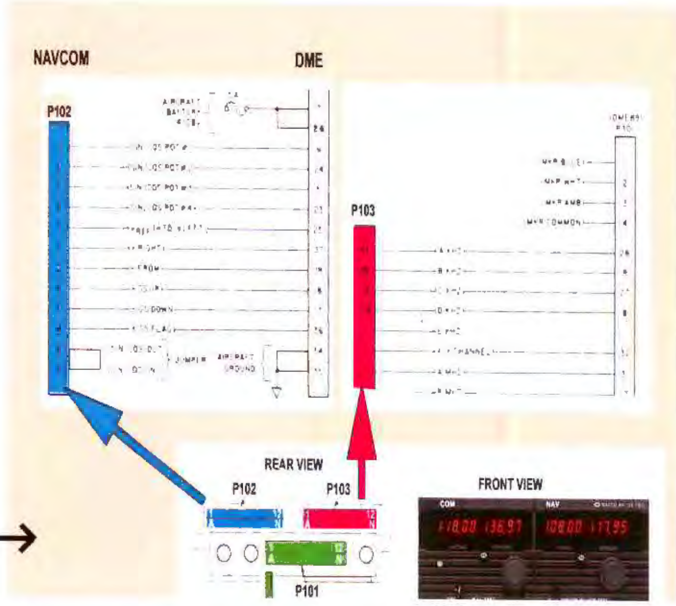
The installation manual gives the location of connectors; see REAR VIEW at the right. It shows three major connectors: P101 (green); P102 (blue) and P103 (red).

(The example shown here is a Narco Mark 12E Navcom transceiver.)

Pin Assignments



1. POWER GROUND
2. NAV 13.75 V
3. SPARE
4. SPARE
5. SPARE
6. SPARE
7. SPARE
8. SPARE
9. + DOWN
10. + UP
11. - GS FLAG
12. + GS FLAG
13. ILS MODE
14. BCD FREQ 1 MHZ
15. SPARE
16. SPARE
17. BCD FREQ 8 MHZ
18. SPARE
19. BCD FREQ 0.2 MHZ
20. BCD FREQ 0.4 MHZ
21. BCD FREQ 0.8 MHZ
22. BCD FREQ 0.05 MHZ
23. SPARE
24. SPARE
25. BCD FREQ COMMON



A connector, like the one shown at the far left, may branch out to different destinations.

(Left) Pin assignment diagram is useful when wiring a connector, even though the same information appears on the main schematic

Reading the Wiring Diagram

The parts on a wiring diagram---connectors, cables, terminals, etc.---are not laid out like they appear in the actual radios. Components may be shown next to each other on a diagram, but lie at opposite ends of the radio enclosure. If the designer drew wires as they actually run, the diagram would be impossible follow. Wires would criss-cross everywhere and the diagram difficult to trace. In the diagram, wires are arranged to run in straight lines.

Some schematics look complex, but there are ways to make them simple. Don't begin the job by identifying the wires, but first look at where they originate and end. By far, most wires begin and end at connectors. Some connectors are part of the radio, while others are at the ends of wiring harnesses.

Sometimes it's difficult to match a connector with its symbol on the diagram. The connector may be identified only by, say, "P302." Look in the manual for other illustrations, such as photos or drawings, that show where P302 is found on the radio. It's helpful to identify the location of every connector before beginning a wiring job.

Schematic symbols

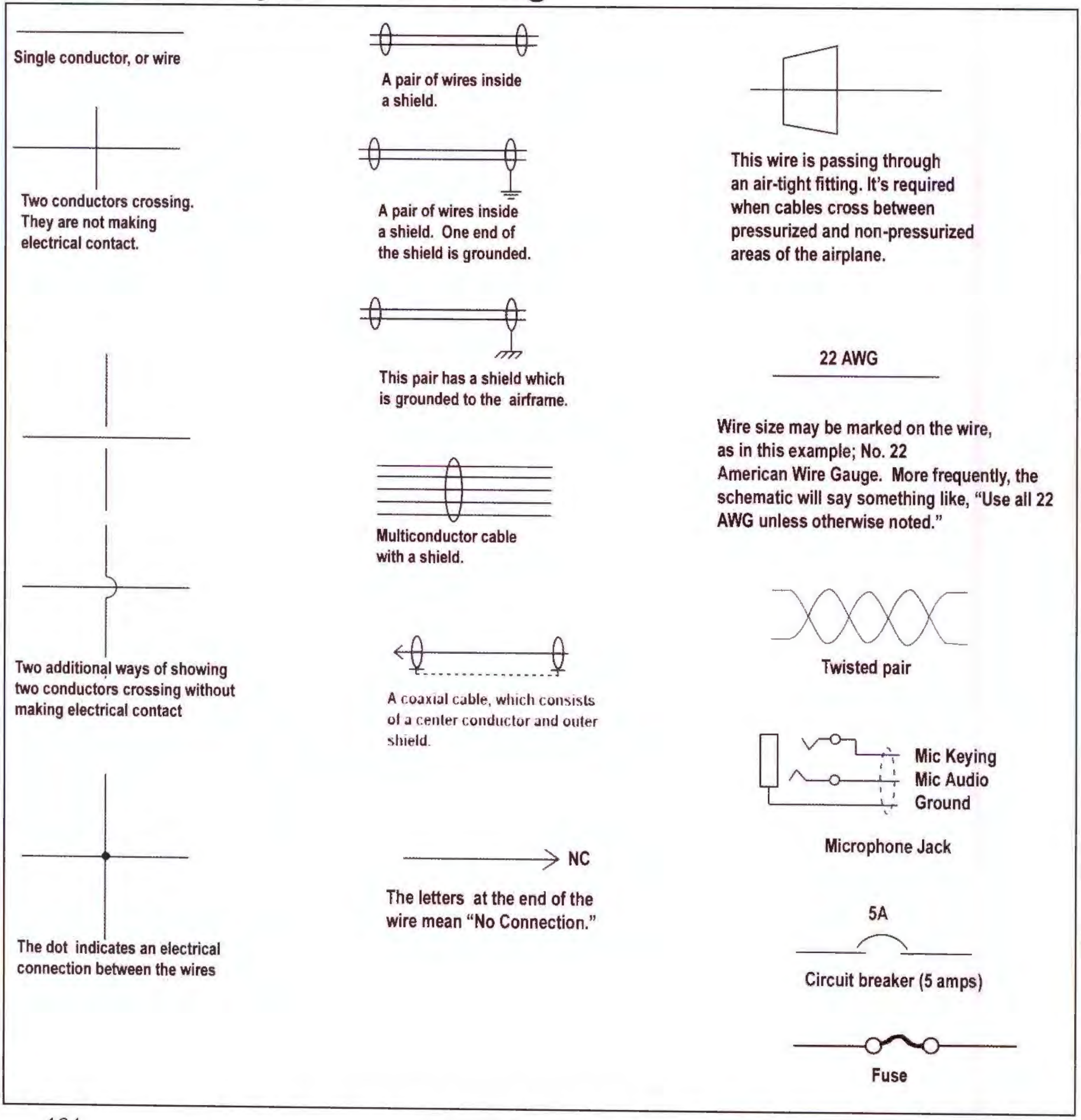
Symbols in schematics are not standard and vary from one manual to the next, but they're not difficult to learn. (Examples are shown in the illustration.)

Most important is to identity the type of wiring required; twisted pair, shielded pair, coaxial cable, for example. The manual gives wire size and type required by each connection . Be sure to read the fine print at the bottom of the schematic because that's often where the information appears. It may say, for example; "Use No. 22 wire except where noted."

Grounds

One item to be careful about is what the schematic says about grounding. Cables that have a shield need to be grounded (to provide a return path for one side of the circuit). But check the schematic carefully for where to make the ground. In some cases, it says in a tiny foot

Schematic Symbols for Wiring



note; "Connect to the nearest airframe ground."

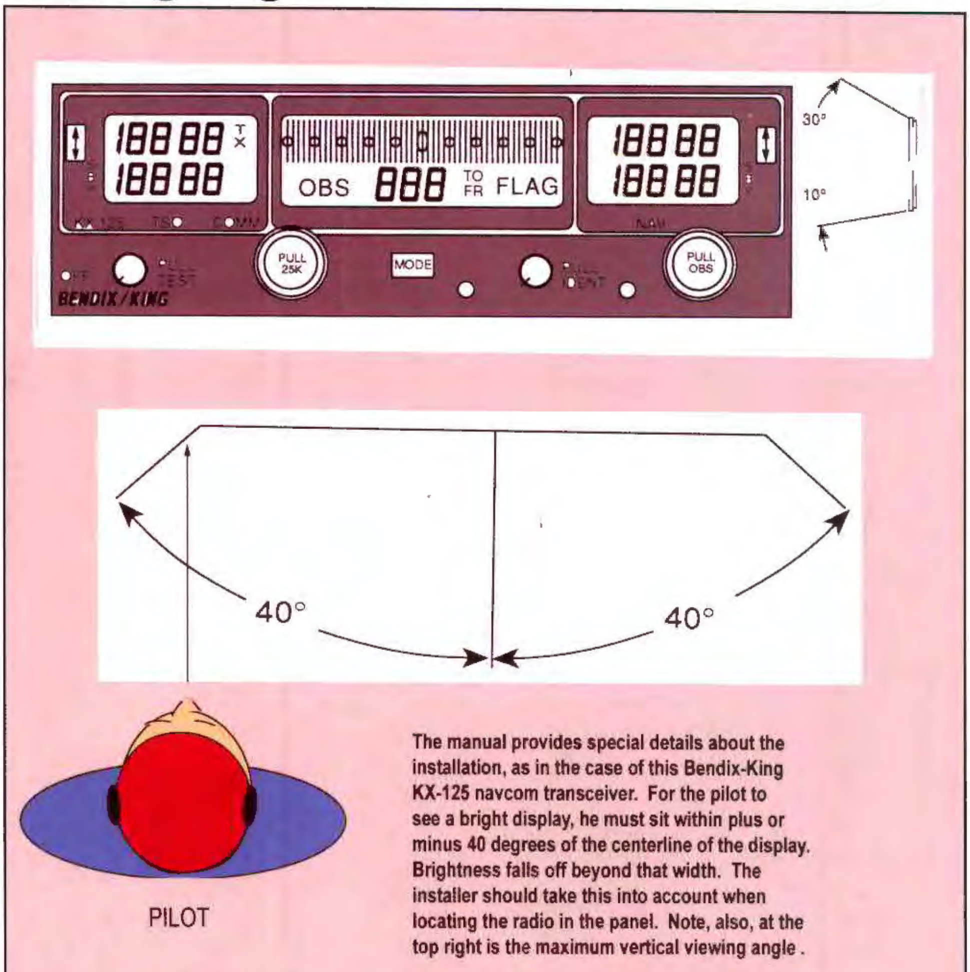
Sometimes it is stated as: "Connect to A/C (aircraft) ground," which is also the nearest airframe ground.

Many circuits, however, require grounding at only at one end of the cable. Study the diagram and footnotes to be sure. Grounding incorrectly causes interference and poor performance.

Location Restriction

The manual warns about certain mounting limitations. FAA rules say that knobs, switches and controls operated by the pilot must be clearly labelled for function and lie within easy reach for operation. The installation manual may add a specific caution, like the one on viewing angle shown below.

Viewing Angle



The manual provides special details about the installation, as in the case of this Bendix-King KX-125 navcom transceiver. For the pilot to see a bright display, he must sit within plus or minus 40 degrees of the centerline of the display. Brightness falls off beyond that width. The installer should take this into account when locating the radio in the panel. Note, also, at the top right is the maximum vertical viewing angle.

Typical Navcom Connections

1. POWER INPUT
2. GROUND
3. MICROPHONE KEY LINE
4. MICROPHONE AUDIO
5. COM AUDIO
6. NAV AUDIO
7. SPEAKER OUTPUT
8. AUX AUDO
9. INSTRUMENT LIGHTING
10. SWITCHED POWER
11. KEEP ALIVE LINE
12. DME
13. VOR/LOC

1. Power Supply

The positive (+) side of the 14- or 28-volt DC source from the airplane electrical system. Also called "A+" it comes from a fuse or circuit breaker designated "navcom."

2. Ground

There are several types of grounds in an airplane. Here, the ground is a path for DC power to return to the negative side of the aircraft electrical system. In aluminum airplanes, it is sometimes the metal structure (which is connected to the negative side of the battery). Some metal parts are insulated from ground by shock mounts made with rubber. To reach ground, mounts can be bypassed with short lengths of metal braid.

There will be many grounds required behind the instrument panel and technicians often prefer to run a separate ground wire from each radio, instrument, etc., to a terminal block behind the panel. A heavy common ground is then run from the block to the negative side of the aircraft battery.

The structure of a composite airplane prevents the airframe's use as a common ground because it will not conduct electricity. Grounds are provided by running a "bus bar," a heavy copper strip or wire from the negative side of the battery to the device being grounded.

When you are required to ground the shield of a wire carrying audio, consult the manual. In nearly all cases, audio leads (for microphones, for example) must be grounded only at one end.

3. Microphone key line.

This lead runs to the press-to-talk button on the microphone. It connects to the microphone jack, specifically to the terminal that connects to the tip of the mike plug.

4. Microphone audio

This carries audio (voice) from the microphone jack to the radio. On the mike jack, this is the center terminal.

5. Com Audio

The voice signal from the receiver. Fed to a headphone jack for listening, it is called "headphone" or "low level" audio. In most aircraft, however, the voice is fed to an audio panel so it can be amplified for a cabin speaker or used with an intercom.

6. Nav Audio

This is audio from the VOR receiver, heard by the pilot to identify the station by a Morse Code or voice identifier. VOR audio may also carry the voice of a Flight Service Station. Most aircraft feed nav audio to an audio panel for listening on headphones or cabin speaker.

7. Speaker Output

Some navcoms have a built-in amplifier for driving a cabin loudspeaker. Otherwise, an audio panel must be added.

8. Aux (Auxiliary) Audio

If the radio has a built-in speaker amplifier, it can take low level audio from other radios and boost it to speaker level. It's usually done in aircraft without audio panels.

9. Instrument Lighting

Also known as the "dimmer" line, it runs to an instrument lighting controller. It enables the pilot, with one knob, to dim radio lights along with other lights on the instrument panel.

10. Switched Power

Use this line when you need to turn on accessories from the power switch on the radio. The VOR indicator, a separate instrument, is one example.

11. Keep Alive

This line bypasses the power switch and goes directly to aircraft battery power. When the radio is turned off, the keep alive line continues powering receiver memory that stores frequencies and other data.

12. DME (Distance Measuring Equipment)

The DME is a separate radio, but is tuned by the VOR receiver. When the pilot selects a VOR, the DME is automatically "channeled" to the correct frequency.

13. VOR/LOC Composite

These are the navigation signals (VOR and localizer) processed by the receiver. They are sent through this line to an indicator for display to the pilot.

Review Questions
Chapter 21 Planning the Installation

21.1 Any major rebuilding of an instrument panel must conform to the airplane's _________.

21.2 When installing new equipment critical to flight, the work must conform to a ___________.

21.3 In planning a major avionics installation, it is important know under what conditions the airplane will be flown. What are three general categories?

21.4 What instruments are in the "Basic T" layout?

21.5 Name two additional flight instruments for instrument flying?

21.6 Before beginning a wiring job, it's helpful to locate and identify every _______.

21.7 Before wiring, determine the size and type of each wire by referring to the _____ ________.

21.8 Wire sizes are often described as "AWG". What does it mean?

21.9 Is a ground wire always connected to the metal airframe?

21.10 When selecting a location on the instrument panel, what is the consideration for viewing angle?

21.11 What is the purpose of "nav audio?"

21.12 What is a "keep alive" line?

Chapter 22

Electrical Systems

AC and DC Power

Avionics and instruments require a variety of voltages and frequencies but they all begin with "primary" power. Most aircraft require low-voltage DC (direct current), which starts at the battery. A major difference is how primary power is distributed throughout the airplane. In light twins and smaller aircraft, power is distributed as 12- or 28-volt DC. Most radios work directly from that source. But in large turbine aircraft, DC is for starting engines and powering some devices. Most electrical power in these airplanes is taken directly from engine-driven generators which produce 115 volts AC. That high voltage is not only distributed throughout the airplane, but is stepped down for recharging batteries. As we'll see, 115 VAC is an efficient method to power a large airplane with hundreds of feet of wire.

A more recent system generates primary power at 270 volts DC. Designed for military aircraft, it looks ahead to the "all-electric" airplane, where electric motors replace today's heavy hydraulic and pneumatic actuators for gear, flaps, flight controls and other mechanical devices. The high voltage---270---carries electrical power with less loss from heating in the wiring.

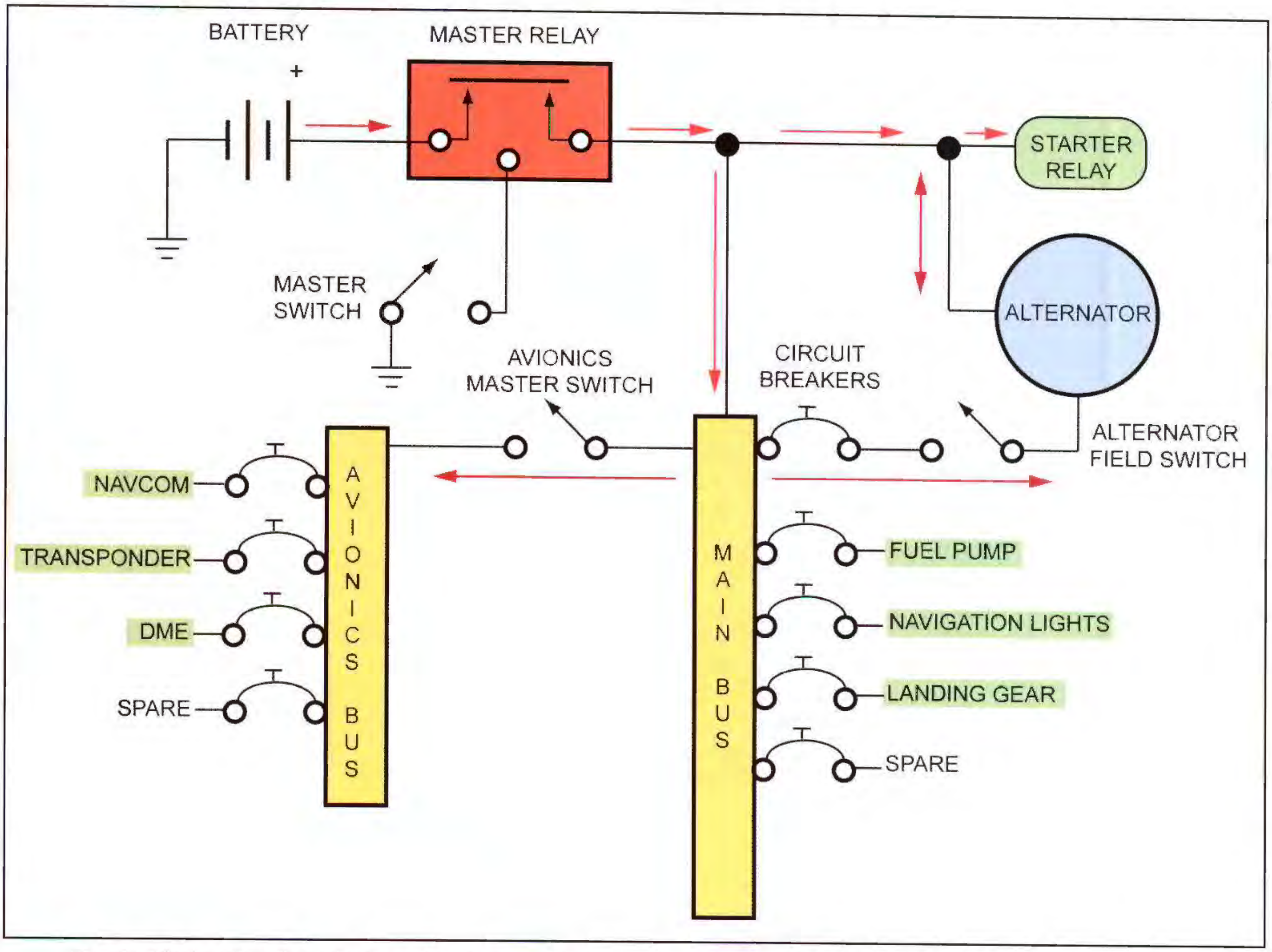
12 VDC. Adapted from the automobile industry, this system consists mainly of an alternator and storage battery. It's called a 12-volt system, but has other names, as well. On some diagrams it's a 14-volt system---on others it's 13.75 volts. But the system is usually called "12 volts." When the alternator is recharging the battery voltage rises to over 13. On schematic diagrams, you may see "13.75 volts" because the circuit designer wants you to use that voltage while operating the radio on a test bench. By adjusting to

12-volt Battery: Percent Charge

- 12.70 volts 100%
- 12.50 volts 90%
- 12.42 volts 80%
- 12.32 volts 70%
- 12.20 volts 60%
- 12.06 volts 50%
- 11.90 volts 40%
- 11.75 volts 30%
- 11.58 volts 20%
- 11.31 volts 10%
- 10.50 volts 0%

Voltages measured at the terminals of a storage battery drop with the state of charge. To measure the capacity of the battery, however, use a tester that puts a load on the battery.

DC System



The electrical system for a single-engine airplane. Starting at the upper left, there is a storage battery with its negative terminal grounded to the metal airframe and engine block. To energize the electrical system, the pilot turns on the master switch which operates the master relay. The relay keeps heavy starting currents from moving through the master switch---and delivers those currents to the starter relay. The red arrows show the distribution of current through the system.

When the engine is running, the alternator generates voltage for recharging the battery and to power the two buses; main and avionics.

The main bus---a heavy copper bar--- powers various electrical devices such as lighting and pumps. Each has a circuit breaker. The "T" at the top of each breaker symbol shows it can be reset by the pilot. In older aircraft there are fuses.

Note at the bottom of each bus a "spare" position. A breaker is installed here when adding future equipment.

The avionics bus originally protected electronic equipment from sudden "spikes" (short bursts of high voltage) while starting the engine and turning on other electrical devices. Modern radios, however, are hardened against such voltages. The main reason for the avionics bus today is a convenience for the pilot: he may turn on all avionics with one switch. Because all avionics are lost if that one switch fails, a second switch is often installed as a backup to restore power.

13.75 volts, the test points measured on the radio should agree with those on the schematic.

28 VDC. As aircraft grew larger, 28 VDC systems were developed. The reason is longer wiring runs and more electrical systems. Because wire has resistance, it wastes part of the current as heat. By raising primary voltage to 24, less current flow is required (for the same power). It's the same reason cross-country transmission lines operate at nearly 1 million volts to carry electricity hundreds of miles with little heating loss. In an airplane, higher primary voltage means less weight and less copper. It also allows more wires to bundle together without causing excessive heat.

By the 1960's light aircraft also switched over to 24-volt systems for the same reasons.

Don't Shock the Airplane. When powering an airplane on the ground during maintenance, be sure the ground power unit will deliver the correct voltage, frequency and amperage. The plug and socket shapes make it difficult to make a mistake, but there are enough instances of "smoking the electronics" on an airplane to observe this precaution.

115 volt Systems. With the arrival of large aircraft, airframe manufacturers began installing 115-volt AC electrical systems. This introduced two power-saving techniques. First, voltage went higher---from 24 to 115---raising the efficiency of power distribution throughout the aircraft. Note, too, that power is now "AC"---alternating current---instead of 12- or 24-volt DC, direct current. The advantage of AC is an ability to easily step it up or down to any voltage and convert (or rectify) it to DC.

115 VAC @ 400 Hz. You may recognize "115 VAC" because it's the voltage in many countries for ordinary house current. This voltage, however, is delivered at 50 or 60 Hz (cycles per second). In an aircraft the voltage is 115 VAC, but frequency is 400 Hz. The higher frequency reduces the size and weight of transformers which change the voltage for various aircraft electrical and electronic equipment.

Any power-generating system aboard an airplane, large or small, is held to a constant voltage by a regulating system. This is important since generators are driven by an aircraft engine that is changing RPM during climb, cruise and descent.

Because a 115 VAC system operates at 400 Hz, it requires *frequency* regulation to hold the 400 Hz steady as the engine changes speed.

Constant Speed Drive. A system to solve the problem is the CSD, or constant speed drive. It contains an oil-driven hydraulic unit and a (mechanical) differential. A governor senses when generator speed is too high or low, and adjusts hydraulic pressure accordingly to keep RPM constant to the generator. When the constant speed drive is constructed in one case with the generator, the system is known as an IDG, for "integrated drive generator."

Check Power Supply Voltage. When selecting equipment for installation, determine the required supply voltage. Old equipment usually works on only one voltage and the manufacturer offered two different models, one for 12 (or 14) VDC and another for 24 (or 28) VDC. The trend today is to offer models with selectable 14 and 28 supplies built in. In some equipment, the manufacturer simply states the radio works on any voltage between 10 and 30 VDC.

Low voltage caution. When doing avionics work on an airplane in a hanger, it is convenient to turn on the master switch to test the installation. Do it for only brief periods (if at all) to avoid discharging the battery. As shown by the chart, a fully charged battery puts out 12.7 volts; a battery with only 10 percent charge produces 11.31 volts (and there may be other losses in the system, such as corroded connections to bring down the voltage further).

Another problem is that some radios automatically switch off to protect themselves during low voltage. It may lead you to believe the radio is bad, when the fault is low primary power. This can waste a lot time during troubleshooting. The cure is to plug a ground power unit into the airplane and be sure voltage is adequate.

Auxiliary Power Unit (APU). Located in a wheel well or near the tail, the APU can power the airplane while on the ground. It is driven by a small turbine engine which turns a generator similar to those mounted on the engines. In many aircraft, the APU may be started and operated in flight to supply emergency backup power.

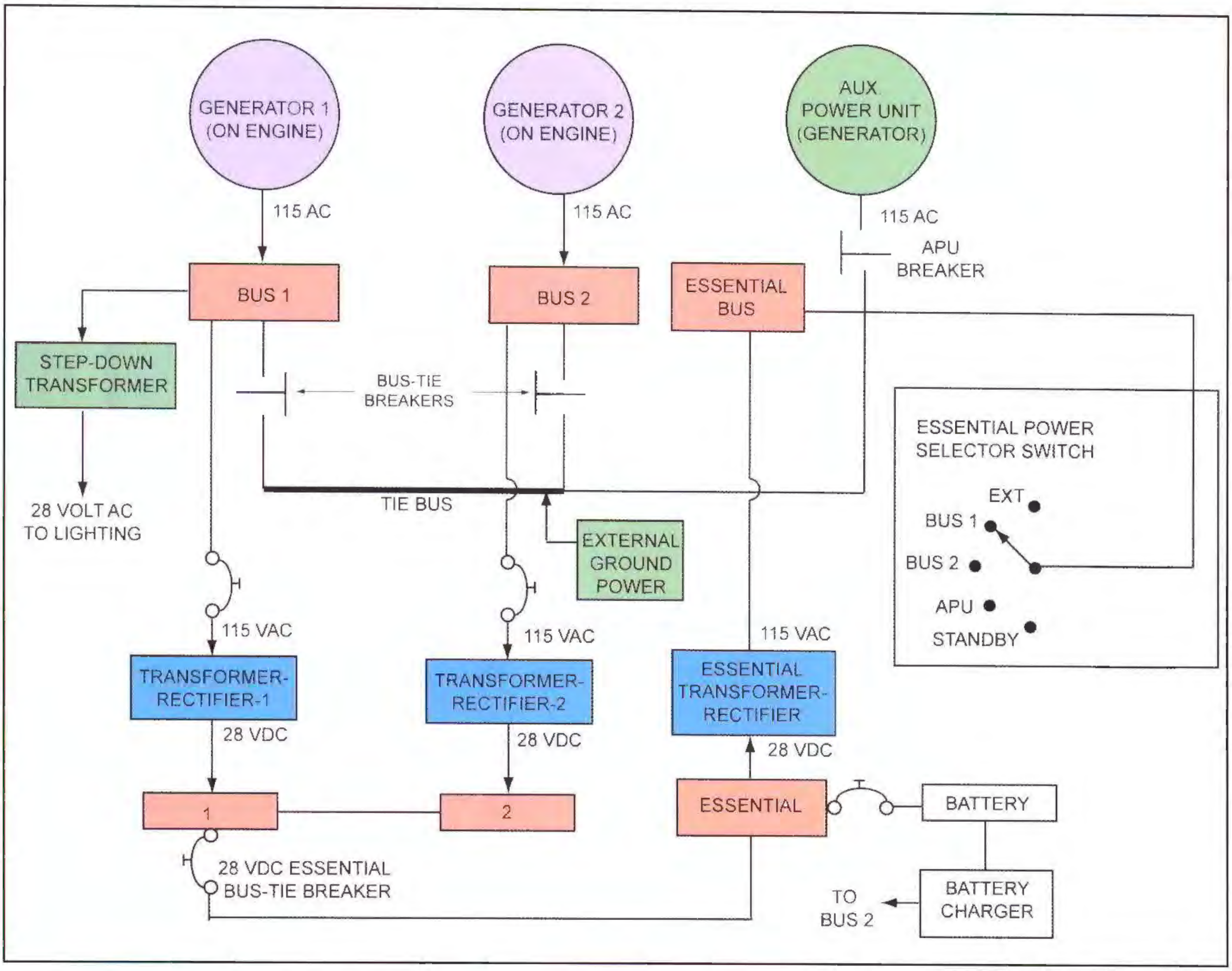
Tranformer-Rectifier Unit

AMPS	VOLTS DC	APPLICATION
20	28	USAF F-15E
50	12	747-400, 777
65	28	727, 737
75	28	747, L1011
75	28	MD-10, MD-11
120	28	757, 767, 777
125	28	S-92, KC-135
150	28	USAF F-15 Fighter
150	28	USN F/A-18 Fighter
150	28	Global Express®, KC-10
200	28	UH-60/SH-60 Heli, KC-135
250	28	Gulfstream G-V, VC-10

ELDEC

Transformer-Rectifier Units are in a variety of aircraft to reduce the output of engine-driven generators (115 volts AC) to low voltage DC (12 or 28).

Airline Electrical System



Simplified diagram of the electrical system for a large air transport twinjet. It is designed to give the pilot many options for restoring power in the event of engine failure or other interruption to electrical power. The main features of the system:

Power is produced by two engine-driven generators at 115 VAC, 400 Hz. This is applied to Bus 1 and Bus 2. Normally, the buses are tied together.

A third generator is the Auxiliary Power Unit (APU), operated by a small gas turbine engine located in a wheel well or tail area. The APU provides power to the instrument panel, lighting and other devices while the airplane is on the ground and main engines are off.

The "essential" bus can power equipment essential to flight (that is, enable the pilot to make a safe landing after power failures). The pilot can directly connect to the aircraft batteries which supply 28 VDC to a standby inverter (not shown). The inverter changes 28-volt battery power to 115 VAC.

Note at the right side of diagram an "Essential Power Selector Switch." This gives the pilot a choice of sources:

EXT: External refers to power obtained on the ramp from a Ground Power Unit.

BUS 1 (Engine generator)

BUS 2 (Engine generator)

APU: Auxiliary Power Unit. (Some aircraft cannot operate the APU in flight.)

STANDBY: Power is drawn from a standby inverter which is driven by battery voltage. The inverter produces 115 VAC which powers essential equipment. This is selected if both engines fail.

Total engine failure in multiengine aircraft is not common, but can happen. Recent examples in airliners include fuel exhaustion due to damaged fuel lines and running out of fuel because of long holding patterns. One Boeing 747 had all four engines fail when the airplane penetrated the ash cloud of an erupting volcano.

RATS. Meaning "Ram Air Turbine System," this is a small propeller that drops out of the belly (in flight) when all other power sources fail. It generates just enough power to keep the pilot from losing control of the aircraft, plus a few more amps. How can a modern air transport with three or more engine-driven generators and storage batteries ever run out of power? By losing all engines. This happened when a fuel leak on a large twinjet sprayed fuel overboard while the airplane was over the mid-Atlantic. The airplane had enough altitude to glide over a half-hour and make a dead-stick landing at an airport, with no injury to crew or passengers. The "RATS" supplied just enough power to control and communicate.

Switches

Switches give long and dependable service, but they contain mechanical contacts and springs which wear during each operation. Electrical arc'ing erodes the contacts and airborne grease enters the housing. Mechanics report that switches on the pedestal between captain and co-pilot are especially vulnerable. The pedestal is used as a convenient tray for coffee and soft drinks. One popular cola is said to be the most corrosive liquid a pilot can spill into the switches.

New avionics equipment often have buttons of the "membrane" type, with no cracks for liquid to enter. But tens of thousands of airplanes will have old-fashioned unsealed switches for a long time.

The loss of a switch is serious, even in aircraft with much redundancy. When pilots operate at a high workload (such as approaching a busy airport during low visibility) it's no time to deal with a switch malfunction. Much of the problem is eliminated by using aircraft-rated (Mil-spec) switches, which are more rugged and reliable than switches for other industries.

Nominal System Voltage	Type of Load	Derating Factor
28 VDC	Lamp	8
28 VDC	Inductive (relay, solenoid)	4
28 VDC	Resistive (heater)	2
28 VDC	Motor	3
12 VDC	Lamp	5
12 VDC	Inductive (relay, solenoid)	2
12 VDC	Resistive (heater)	1
12 VDC	Motor	2

1. How to find required "Nominal" switch rating

A. Obtain from the equipment manual the current rating of the lamp, motor or other load the switch will control

B. Select (above) "Nominal System Voltage" (28 or 12).

C. Select "Type of Load"

D. Multiply switch rating by the "Derating Factor." The answer is the switch "Nominal" rating in amperes

2. Next find the "Continuous" current that switch can handle.

A. *Divide* the "Nominal" rating (obtained above), *by the* "Derating Factor" (using the same voltage and type of load.

Caution on mounting position. If you look at a switch it may be difficult to tell which is the "on" position. The terminals on the back are symmetrical, and may look the same either way. Some switches have a small nameplate with "on" that slips over the handle when the switch is bolted to the panel. Failing to observe the correct "on-off" position while mounting a switch can have serious consequences. In one actual incident, a technician installed a new magneto switch and reversed its position. With the handle "up," the magneto was off. In the down position, it was "on." This is opposite to the standard "up is on, down is off." When another mechanic fueled the airplane he pulled the prop through by hand with the magneto switch "off." The engine fired---the switch was actually "on"--- and spun the prop around with great force. Fortunately, the blade did not strike the mechanic but disaster was only inches away.

Check a switch before installation with an ohmmeter. Select the "R x 1" scale, place the probes across the terminals and you'll read zero resistance for contacts that are closed, infinite resistance when open. And when working around airplanes treat every prop as if it is alive.

When checking a switch that's been in service look for any sidewise movement of the handle. Even though the switch can turn the power on and off, replace it. Wobbling is a sure sign of early failure.

Select the Switch Rating. Different loads have different effects on switches. Turning on a lamp sends high current into the filament because it has low resistance when cold. This also sends a large inrush of current through the switch, which may be 15 times greater than when the lamp is operating. Switch contacts must withstand that by "derating"---selecting a higher current rating. Otherwise, contacts may weld together or corrode as heavy current flashes over.

When a switch controls a device with a coil of wire, such as a relay, it also needs derating because of "inductive kickback." As the coil is energized, it stores energy as a magnetic field. When the switch is opened the field collapses and "cuts across" the coil, inducing high voltage across the switch. The contacts burn and pit, which is avoided by derating the switch.

Avionics Master. This switch originated as a method for protecting early models of solid-state radios. It enabled the pilot to keep all avionics off while cranking the engine to prevent damaging voltage spikes from reaching the radios. It also protected radios against low voltage as the starter drew heavy current from the battery. These problems were common to the first generation of transistorized equipment; avionics today have built-in devices to protect against surge and low voltage protection.

But the avionics master is still widely used because it is a convenience for the pilot. Instead of flipping a half-dozen switches or more, he throws one switch to turn on all avionics.

This convenience, however, comes at a price. It's the *single-point failure*. If the avionics master switch fails, it disables all radios in the airplane. A solution in light aircraft is to wire a second switch across (in parallel with) the avionics master. Using the back-up switch restores the lost power.

There are more advanced methods for keeping radios working in the event of failure of the master switch, the master relay or from other interruptions to the primary power. Some technicians install an "essential" bus, which is a wire directly from the battery. Multiengine aircraft have dual electrical systems to prevent the single-point failure.

CIRCUIT BREAKERS

The purpose of a circuit breaker is to protect wiring, not the equipment. Most recent avionics already have overvoltage protection. The hazard is that a wire carrying excessive current may heat and cause smoke or fire. By placing the breaker close to the power source, more of the wiring is protected.

The size of a circuit breaker---its rating in amperes (amps)---is selected so it opens before current exceeds the capacity of the wire. The chart shows the size breaker or fuse for different levels of current in DC circuits.

Switch Types

1. Toggle Switch
This switch has a "bat" handle (resembles a baseball bat). Sometimes several are ganged together with their handles linked. It assures that all switches are thrown at once in same direction.

2. Pushbutton switch.
Used when a circuit is operated for a short time, such as the push-to-talk switch on a microphone. It has a spring-loaded button. Depending on the circuit, the switch may be push-to-make (contacts close) or push-to-break (contacts open).

3 Rocker switch
The pilot pushes the top half of the rocker switch to energize the circuit, the bottom half to break the circuit.

5. Rotary switch
Enables several circuits to be selected with one knob. It also is more resistant to being knocked off its position (which can happen in rocker and toggle switches).

6. Microswitches
The name is from the few thousandths of an inch between contacts on the make and break. They have snap action. These switches are operated by the pilot, or located at different points on the airplane to sense a mechanical position. An example is a retractable landing gear; when the wheels are down and locked they operate microswitches that illuminate lights on the instrument panel.

7. Pressure switch.
These are often used to warn when pressure in a hydraulic or pneumatic system is too high or low. It's usually done through a flexible disk (diaphragm) which moves with pressure. It operates switch contacts and indicator lamps.

8. Thermal Switch
Used to warn of overheating in a component (a generator, for example) and to sense and indicate an engine fire. It works on a bi-metal thermostat that curves with heat and makes an electrical contact.

9. Proximity Switch
Are doors and hatches on the airplane closed and locked before take-off? This is done with proximity switches. One half is a housing containing two strips of metal mounted parallel with each other. This may be fixed to the door frame. On the door is a permanent magnet. When the door is secured, the magnet pulls the metal strips together to operate a warning light in the cockpit.

Description	Off	Illuminated
Hidden Legend		AAI
Hidden Legend Lighted Background		AAI
Lighted Background	AAI	AAI
Lighted Letters	AAI	AAI

AAI

Variety of choices for illuminated pushbutton switches. Note in the lower two examples, the label ("legend") is visible even when the switch is turned off.

Recessed button type. When an overload occurs it will, as commonly said, "Pop the breaker." This is because heat in the breaker opens a pair of contacts. The button on the breaker pops out and the circuit remains open until the pilot pushes it in. However, if this is done quickly, the breaker may not remain engaged because it is still cooling down. Wait a moment and try again.

A pilot or technician will always attempt to reset the breaker to see if the problem is gone. After three attempts to reset the breaker with no success, you can assume the short-circuit didn't go away.

Resettable breaker ("Push-Pull") This breaker style has a knob so the pilot can pull it and break the circuit, as if it's a power switch. This becomes a diagnostic tool for the pilot who experiences an electrical problem in flight. He can "pull breakers"---one by one--- in an effort to make the problem go away. If it does, he can leave the breaker open to disable the defective equipment.

If the breaker is "trip-free," it means it cannot be reset if the overload still exists when the button is pushed in.

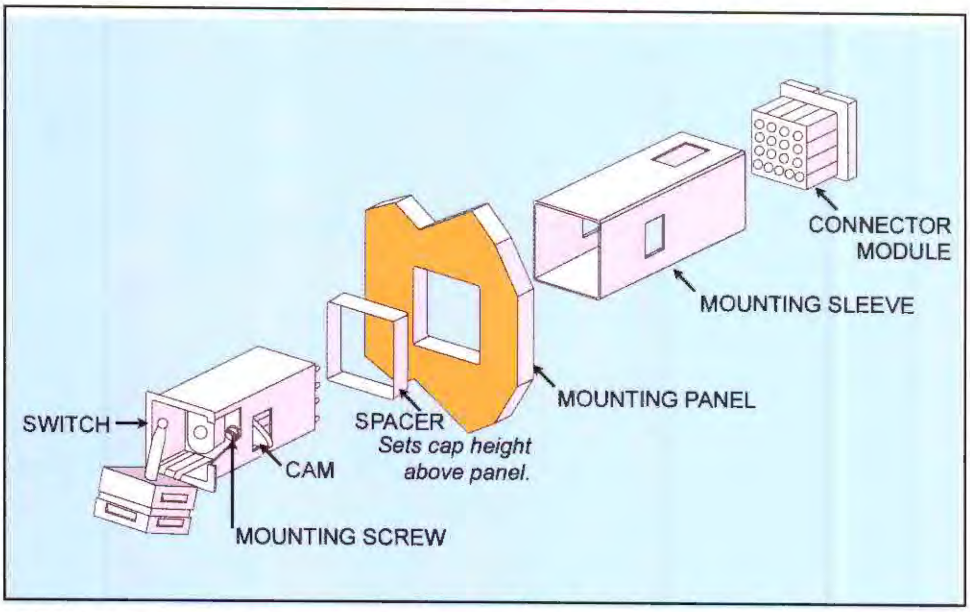
Automatic reset breaker. Some circuit breakers are designed to break the circuit, then automatically reset later, when the internal element has cooled. These breakers ***are not recommended*** for aviation. Although the problem may have cleared, there may be enough heat remaining in surrounding metal objects to keep the breaker open for a long period time. This happened to one pilot with a problem in a landing gear motor. An automatic circuit breaker sensed excessive heat in the electrical motor and opened the circuit. This prevented the wheels from dropping and locking. Although the overload had cleared, the breaker was mounted on the case of the motor, which is a large mass. It acted as a heat sink and continued to hold the breaker open. As a result, the pilot made a wheels-up landing that damaged the prop, engine and belly. If he had known the landing gear motor would cool and reset the breaker---probably within 20 minutes---the accident wouldn't have happened. A better design is to run the gear motor electrical power through a breaker under control of the pilot.

Pulling breakers and nuisance alarms. Experts in human factors know about "nuisance" alarms. If a warning keeps sounding when there is no problem, pilots will turn off the system. They do this, even though the system has no off switch. They simply "pull the breaker." This happened in the early days of "ground prox" (ground proximity warning system), which had many false alarms. Instead of blaming the pilots, the manufacturers went back to their drawing boards and redesigned the system.

Breaker locks. There is a device that can be put under the button of a circuit breaker to prevent it from being pushed in. It's a temporary measure used by technicians during maintenance to be sure a defective piece of equipment will not have power applied accidently.

Maintaining breakers. A good practice is to pull the knob of a circuit breaker in an out several times if it appears unreliable. Do this while the equipment is off and no current is flowing. Operating the breaker cleans the contacts and reduces electrical resistance.

Lighted Pushbutton Switch



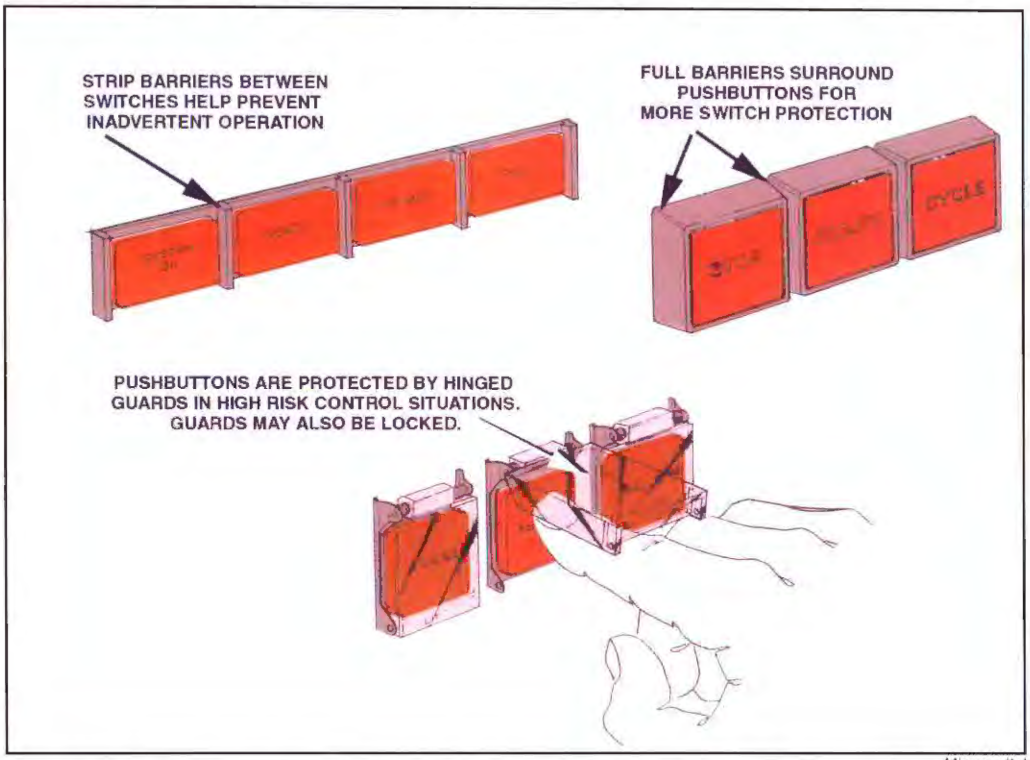
Improved lighted pushbutton switches, like this Korry model, eliminate a major source of maintenance; replacing lamps with burned-out filaments. Lighting is supplied by bright LED's (light emitting diodes) that can last the life of the airplane. They also run cooler than conventional lamps.

A pull-off cap (lower left) provides access to the switch, which can be removed by a mounting screw and cam. The switch itself may be four independent microswitches, an arrangement which eliminates switch "chatter" during shock and vibration.

The external connector module (upper right) carries wiring to the switch through crimped connector terminals. A "poke home" push engages the switch into the connector module.

These switches are made for 5 or 28 volts commonly found in instrument panel lighting. Electronics for dimming the light are built into the switch.

Switch Guards



Microswitch

A pilot may push the wrong switch while flying in turbulence. Barriers between rows of switches reduce that problem. In the bottom drawing, switches are covered by a guard which must be lifted.

Fuses

The convenience of circuit breakers has reduced the number of fuses---which burn out after one overload. For this reason, fuses should be accessible to the pilot for changing in flight.

Heavy duty fuses are found where large amounts of electrical power concentrates at distribution centers on the aircraft. In some installations, a built-in lamp illuminates when the fuse "blows."

Another form of fuse is the current limiter, also used in high wattage locations. It can pass a large overload without breaking the circuit, aided by a ceramic housing which can take the heat.

Circuit breakers during construction of a panel Note that each breaker is temporarily labelled with a felt-tip pen. This helps identify the wiring and final testing. After the panel is painted, machine-made labels are applied.

Recessed Button Breaker

Circuit breaker panel using "recessed button" type breakers. Having no buttons protruding from the panel, they cannot be pulled out by the pilot to disable a circuit.

When a breaker "pops," the button comes out and remains out so long as there is an overload. It cannot be reset (pushed in) until the problem is cleared.

Occasionally a breaker cannot be reset, even though the overload is no longer present. If this happens, wait a minute or two for the thermal element in the breaker to cool and reset.

If a breaker pops and you reset it, the circuit may continue to operate for a while, then pop the breaker again. When that happens, it is good practice to reset the breaker only three times. After that, the source of the overload needs investigation.

Review Questions
Chapter 22 Electrical Systems

22.1 The primary electrical source in most airplanes is low voltage DC (direct current). What are the two most common voltages?

22.2 In a light aircraft, connection to the battery is completed by the ___________.

22.3 A heavy copper bar that distributes power to most electrical systems aboard the airplane is called the ________ _______.

22.4 A heavy copper bar that distributes power only to radios and related equipment is called the ________ ________.

22.5 Large aircraft distribute power in the form of alternating current (AC) at ________volts. The frequency is ________.

22.6 What is the main purpose of an APU (auxiliary power unit) in a large aircraft?

22.7 What is the meaning of RATS, and how does it work?

22.8 Why must switches have the ability to handle more current than required during normal operation?

22.9 What is the primary purpose of a fuse or circuit breaker?

Chapter 23

Mounting Avionics

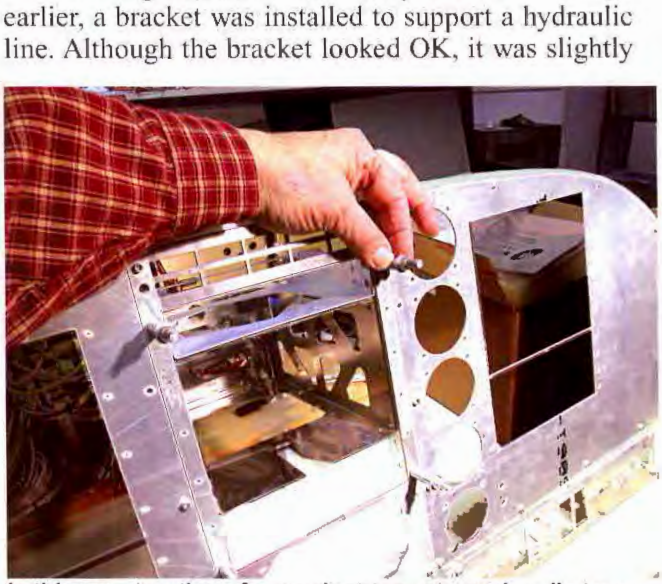
Most vehicles operate in two dimensions (left and right, forward and back). Airplanes move *six* ways; around their own axes; pitch, roll and yaw (3)---and they move forward, climb and descend. Combine these motions with gravity and acceleration, and it's easy to see why an airplane is not airworthy unless its components are secured in a strong structure.

Airplanes are also short on space. Equipment is squeezed into crowded areas behind instrument panels, inside a nose or in a small equipment bay. Mounting equipment in compact spaces can generate sufficient heat to cause early failure.

Another hazard is that avionics share space with cables, control columns, chains, gears, levers, motors, pedals, ducts and pilots' feet. One pilot rolled down a runway for take-off and, at flying speed, pulled the control yoke to raise the nose. The yoke would not move. There was enough runway left, fortunately, to re-land the airplane. Looking behind the panel we found an antenna cable wound around the control column, securely locking it in place. Frequent incidents like these prove the critical nature of mounting and wiring avionics and instruments.

Installation problems are not limited to light aircraft. In one close call, three hundred airline passengers nearly met disaster because of a minor mounting bracket. While in cruise, the right engine of a big twin jet suddenly flamed out. Any modern airliner can continue to fly with one engine out, but a half-hour later, the left engine died. The pilots were unaware that a large quantity of fuel was venting overboard. They had enough altitude to land at an airport, suffering no more damage than eight blown tires.

Investigators soon found the problem. Five days earlier, a bracket was installed to support a hydraulic line. Although the bracket looked OK, it was slightly



In this construction of a new instrument panel, radio trays are being riveted to brackets. The brackets were fastened earlier to the panel.

different in size from the correct one. This reduced clearance between hydraulic and fuel lines, causing contact between them. After five days of flying, vibration and rubbing cut the fuel line, which spilled a large quantity out the trailing edge of the wing.

These cautionary tales show how minor discrepancies lead to major problems. In an avionics installation or retrofit, it is not unusual to mount a few hundred brackets, clamps, cable ties, supporting structures and other hardware.

New or Old Installation?

There are various levels of installation. A pilot may want to replace one old radio---or need an upgrade where the panel is extensively refurbished. There is also the "tear it all out and start over again" job.

If the airplane is a light aircraft, the radio shop often designs the installation. When the work affects structures and control systems, large shops depend on the skills of their A&P (airframe and powerplant) mechanics to fabricate brackets, shelves and other supports for the new radios.

Before tackling an installation, the technician runs a weight-and-balance calculation to see if removing and/or adding new equipment exceeds the aircraft's CG (center of gravity) or adds excessive weight.

Airplanes in flight also develop *dynamic* loads while maneuvering, especially in turbulence. If there is any question whether additional support is required, the job should be reviewed by a DER (Designated Engineering Representative) with a specialty in structures. He can design a system that meets acceptable installation practices. A DER is required when cutting through a structural member (such a rib or bulkhead). Large shops often have a DER on staff, while smaller facilities may hire an independent DER on a per-job basis.

STC's. Avionics equipment that is flight-critical is STC'd, meaning the manufacturer applied for a supplemental type certificate. The installation has been worked out in great detail and a kit of components may be supplied. Wherever an STC applies, the installer follows the document carefully for structural and wiring details.

Hostile Areas. Beyond the cockpit and passenger cabin, there is an unfriendly environment for electronic equipment. Engines generate heat and vibration, the airplane flies through large temperature and humidity changes and low areas on the airframe accumulate oil, hydraulic fluid and water. Many radios and instruments are fortified against these hazards with a TSO (technical standard order), which certifies they are built to meet environmental conditions encountered in aircraft.

The manufacturer's maintenance manual is the most valuable source of installation information. Not only does the company have the engineering resources to design the installation, its manual is recognized as "approved data."

Selecting Metal

Offering a good combination of lightness, strength, electrical conductivity and workability, sheet aluminum is the common choice for panels. Aluminum angle and flat bar are selected for fabricating structures such as brackets and supports.

Look for the label "Alclad," which refers to a thin coating (on both sides) of 99 percent pure aluminum. The coating has high resistance to corrosion. Oxidation on aluminum does not have a distinctive color (like rust on iron) and may be difficult to see.

Consider various aluminum stock:

2024. This alloy is often selected for sub-panels that hold instruments, for example. It is not heavy enough for the overall instrument panel. 2024 has good resistance to metal fatigue and bends without cracking.

2024 aluminum can be polished to an almost chrome-like finish.

3003. This grade of aluminum is alloyed with manganese for strength. The material is still easily workable and resists cracks while bending. It is also corrosion-resistant (without Alclad)

3003 is excellent for forming brackets, housings and structures that require a lot of bending and forming, especially where the higher strength of 2024 is not required.

6061. This popular alloy is strong, corrosion-resistant, workable and relatively low in cost. It is available in Alclad for added protection.

6061 is useful in building structures which support the weight of a stack of radios or instruments.

Thickness. Aluminum comes in many thicknesses, measured in thousandths of an inch, for different applications:

.040. This size is good for forming lightweight brackets for supporting cooling fans, switches and other lightweight equipment such as cover plates and glove box doors.

.063 makes sturdier brackets for supporting heavy equipment (a radio stack, for example), panels for headphone and mike jacks and equipment shelves.

.080 This heavy material is suitable for the overall, or main, instrument panel. In this thickness, however, you can make bends only over a large radius.

Cutting Holes

Aluminum is not difficult to punch, cut and file. There are several options, from working it in the shop to sending it out to a specialty house.

Manual cutting. It is possible to cut instrument and other holes with a jig saw and metal-cutting blade. A set of round, half-round and flat files are for finishing touches and smoothing burred edges.

So long as holes are round or rectangular, cutting them may be time-consuming, but not impossible. The problem arises in odd shapes, such an ARINC-type instrument that has bevels on all four sides. This can take much effort to shape by hand-filing.

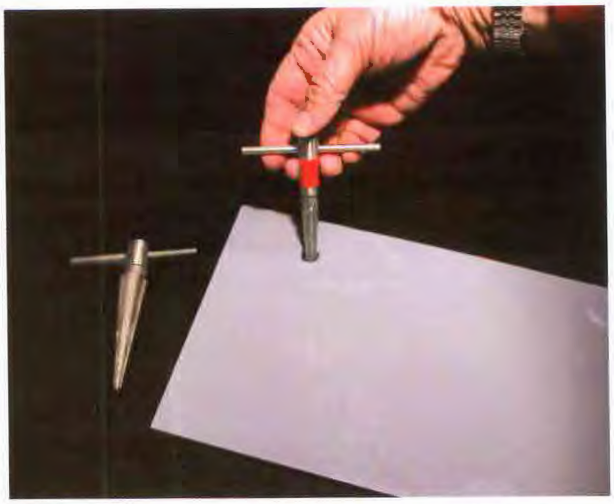
Router. Some shops use a router to cut panel holes. The sheet aluminum is placed on a routing table and, with the aid of a template, holes cut with a router bit designed for aluminum.

Punches. Metal punches are made to the exact size and shape for cutting panels. A pilot hole is drilled in the panel and a bolt inserted to hold a cutting die. Tightening with a wrench drives the halves of the die together for a neat hole. In large shops, a hydraulic driver operates the punch, greatly shortening the time to make the hole.

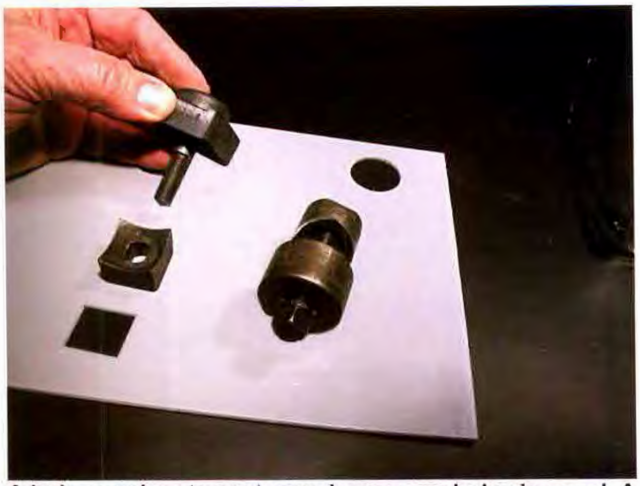
If an avionics manufacturer produces a radio with an odd shape, he may also offer for sale the punch to make that hole.

Laser Cutting. In the newest technique, holes are made by laser beam. Because the machines are costly, such work is often sent out to a specialty shop. The holes are extremely accurate and clean.

To work with an outside house, you design the panel on a PC, using software such as Autocad. The file may be sent to the laser company by e-mail.



A hand reamer cuts holes in panel for switches, controls and other small items. First, a pilot hole is made with an electric drill.



A hole punch cuts neat round or square holes in panel. A square one is at the left, the other is a round one. Punches are also made for cutting odd-shaped holes required by some instruments.

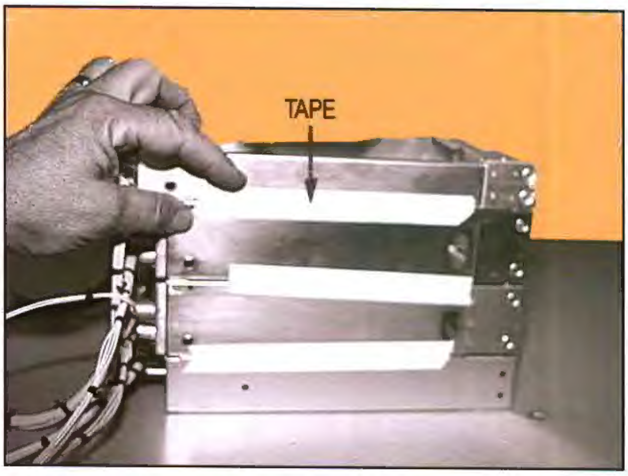
The hole punch cuts into the panel as its nut and bolt are tightened with a wrench.

Structures

"Structures" refers to avionics enclosures and mountings, including cabinets, cases, racks and supports. There are few standard sizes for General Aviation equipment, but for airline and military service, manufacturers are held to strict dimensions. The installation of equipment in any airplane must comply with airworthiness standards for weight, power, secure mounting, labelling and others.

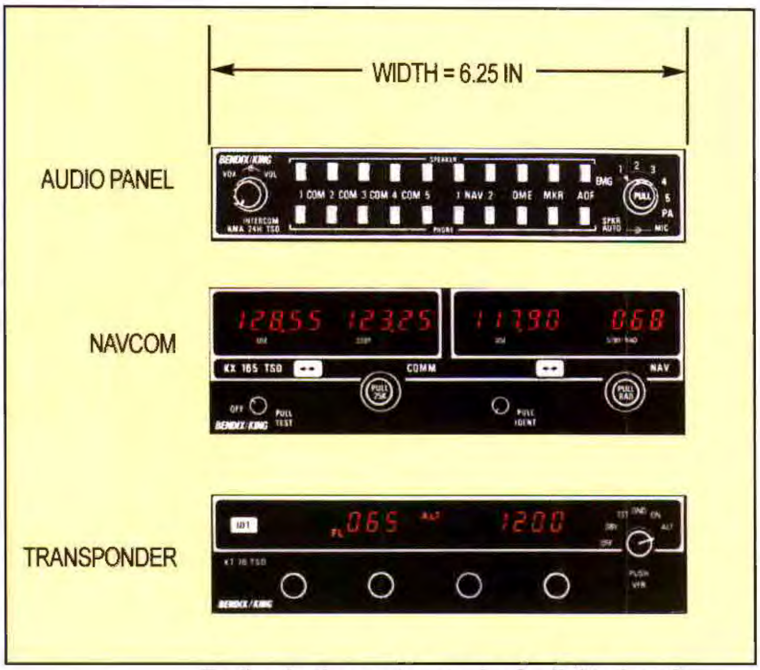
General Aviation

Although GA has no standard sizes, certain customs are followed by most avionics manufacturers. In light aircraft, where radios are usually mounted in a center "stack," the width is typically 6.25 inches. To avoid the mismatch of radios of different widths in the same stack, most radios observe that dimension. Thus, in a simple stack there might be an audio panel at the top, one or two navcoms next and a transponder at the bottom. Their heights and depths are different, but they all fit in the stack.

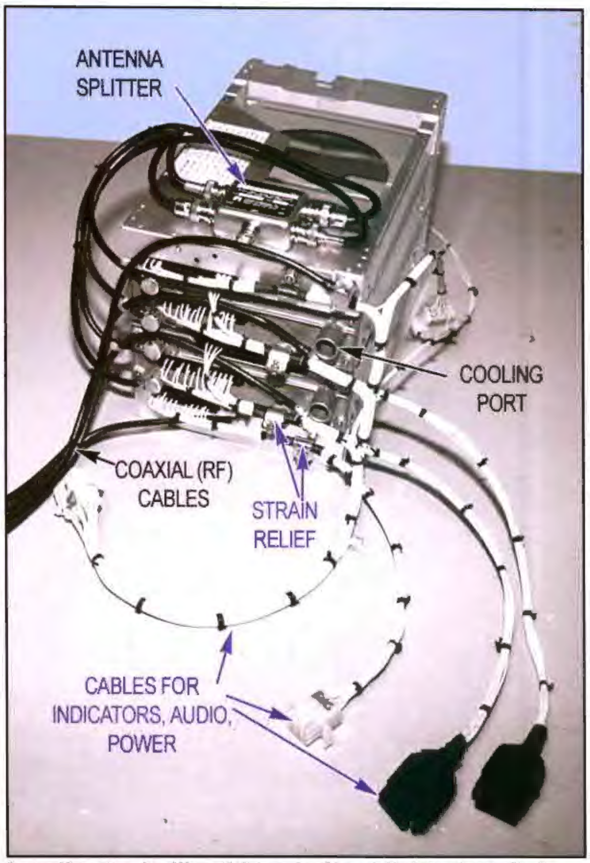


While wiring a radio stack on the workbench, tape the sides of the trays together. This keeps the trays stable while you wire the harnesses at the rear. Remove the tape just before installing the stack in the airplane.

After the stack is installed in the airplane, the forward section (at the right) bolts to brackets on the instrument panel. Brackets should also fasten to the back of the stack (left) to keep trays locked together.



Radios in the center stack of a light aircraft are usually 6.25 inches wide.



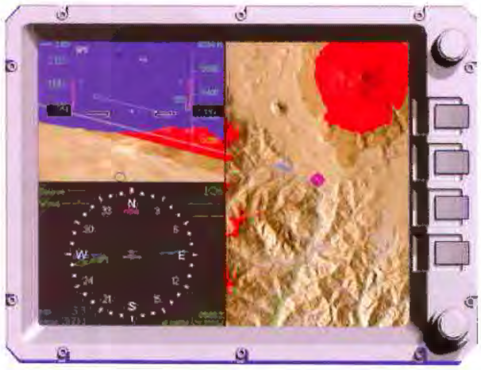
A radio stack, like this one for a light aircraft, is pre-wired on the workbench before installing in the airplane. Three avionics trays are shown; two navcoms on top, with a transponder on the bottom. Wiring is done to connectors mounted on the back of the trays. The radios are slid into place later, and make contact with the rear tray connectors.

EFIS

The future for General Aviation is the electronic instrumentation system (EFIS). The airlines have transitioned to the "glass cockpit" and the trend is well-established in General Aviation. Conventional 6.25-inch wide radios will be here for several more generations, but nearly all new production and experimental aircraft began outfitting with EFIS by 2004.

EFIS systems are often supplied by the manufacturer with pre-cut and pre-wired cables, with all connectors attached at the factory. Because so many systems appear on one screen, fewer holes are cut in the instrument panel.

Will this mean less installation work for the technician? Probably not. From the end of World War II, there's been an ever-increasing stream of new avionics systems, government requirements and airborne telecommunications services (fax, telephone, Internet, etc).



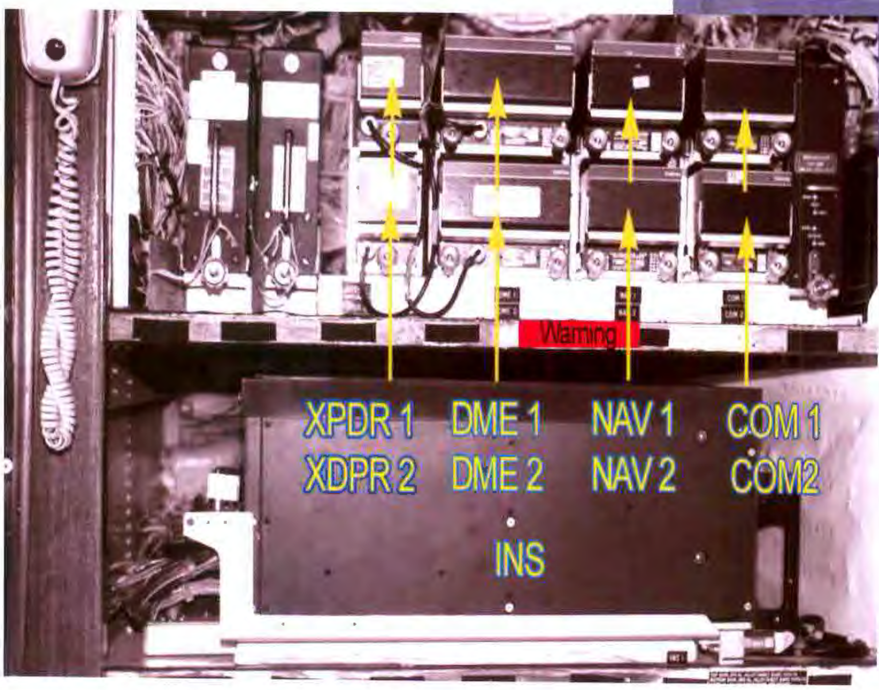
The old "radio stack" will disappear as new and upgraded airplanes, of even the smallest size, are outfitted with EFIS (Electronic Flight Instrument System). This Blue Mountain system combines flight instruments, moving map and terrain warning on one display.

Corporate and Business Aircraft

Larger commercial aircraft---the turboprops and jets flown by corporations--- also do not follow common avionics standards. These systems are usually remote-mounted, with control-display units in the instrument panel, and remote radios mounted in the nose, belly or near the tail.

Avionics Bay of a Corporate Jet

Gulfstream



Most LRU's (line replaceable units) are in the lower fuselage. Examples shown include: transponder (XPDR). DME, NAV (VOR receiver) and Com (VHF). Each radio is duplicated for safety. The large dark area in the center ("INS") is the rack for an inertial navigation system (which has been removed for repair).

The "Warning" placard near the center (in red) cautions against excessive weight. The text says: "Maximum load of radio area not to exceed 750 pounds." This avoids exceeding the airplane's weight and balance limits.

The handset at the upper left enables the technician to talk over the aircraft intercom system.

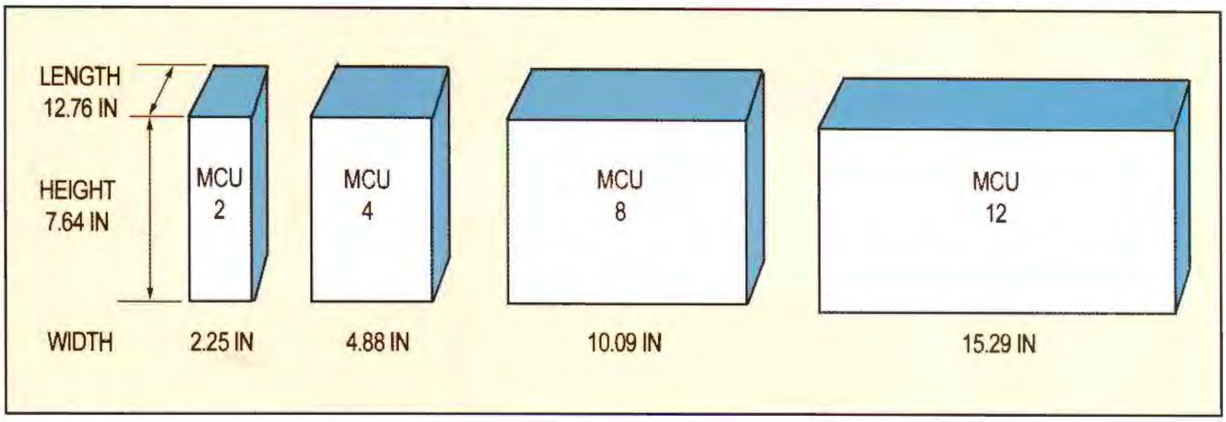
Airline (ARINC) Structures.

The airlines solved their structures problems back in 1929 when they formed ARINC (Aeronautical Radio Inc.). The organization developed standards (called "Characteristics") for mounting and interconnecting each piece of avionics. The specifications, however, apply only to the radio's "form, fit and function." This means an airline can buy a DME from one manufacturer, then 10 years later buy an improved DME from another manufacturer and plug it into the same tray or rack. There's no rewiring or modification Both old and new radios have the same form, fit and function---even though the inside of the new radio may have a different design and internal components.

Two important Characteristics for airline radio structures are ARINC 404 and ARINC 600. The first, 404, contains sizes known as ATR. Although some people interpret ATR as "Air Transport Radio," ARINC says it means "Austin Trumbull Radio," after the developer.

ARINC 600 came into existence with digital avionics. Thus, ARINC 404 represents an earlier, analog era, while 600 is the digital successor. However, it is common for airliners to have a mixture of both 404 and 600 structures and avionics.

MCU Case Sizes (ARINC 600)



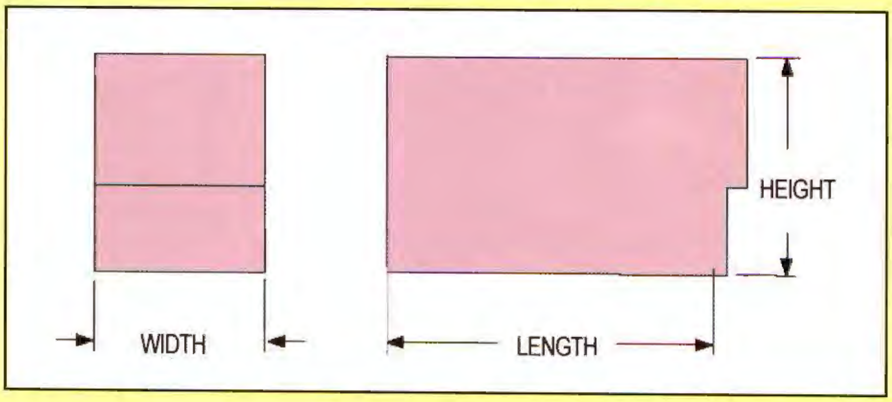
When airliners began converting to digital avionics, new case sizes were developed for LRU's (line replaceable units). Called MCU, for Modular Concept Unit, it was standardized by ARINC 600. The connectors offer many more circuits over ARINC 404. Because "digital airliners" still carry analog equipment, they have a mixture of ARINC 404 and 600 cases.

MCU cases are the same length and height, differing only in width. The table at the right gives a comparison between the two systems:

1 MCU = 1/8 ATR
2 MCU = 1/4 ATR
3 MCU = 3/8 ATR
4 MCU = 1/2 ATR
6 MCU = 3/4 ATR
8 MCU = 1 ATR
12 MCU=1-1/2 ATR

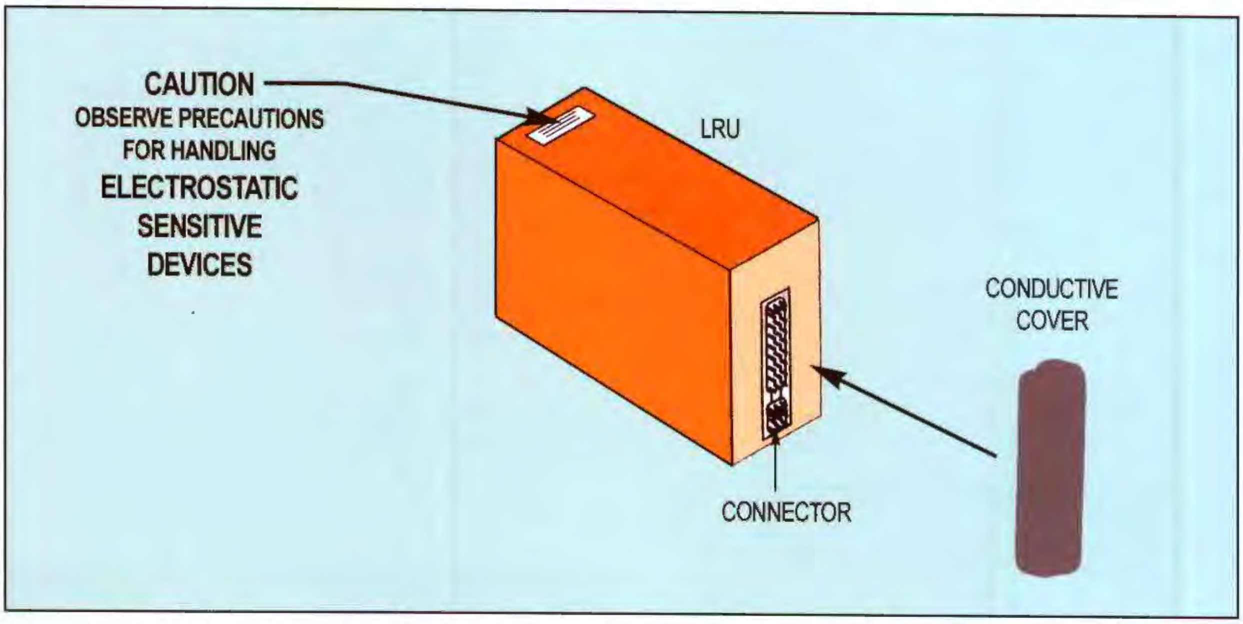
ATR Case Sizes (ARINC 404)

Earlier ARINC 404 case used for analog avionics.



ATR SIZE	WIDTH		LENGTH		HEIGHT	
	INCHES	mm	INCHES	mm	INCHES	mm
Dwarf	2.25	57.15	12.52	318.0	3.38	85.8
1/4 Short	2.25	57.15	12.52	318.0	7.62	193.5
1/4 Long	2.25	57.15	19.52	495.8	7.62	193.5
3/8 Short	3.56	90.41	12.52	318.0	7.62	193.5
3/8 Long	3.56	90.41	19.52	495.8	7.62	193.5
1/2 Short	4.88	123.95	12.52	318.0	7.62	193.5
1/2 Long	4.88	123.95	19.52	495.8	7.62	193.5
3/4 Short	7.50	190.50	12.52	318.0	7.62	193.5
3/4 Long	7.50	190.50	19.52	495.8	7.62	193.5
1 Short	10.12	257.05	12.52	318.0	7.62	193.5
1 Long	10.12	257.05	19.52	495.8	7.62	193.5
1 1/2	15.38	390.65	19.52	318.0	7.62	193.5

Electrostatic Discharge (ESD)



Microcircuits bring great benefits to avionics, but they create a new problem; "ESD," for electrostatic discharge. Components are so tiny, they are susceptible to static electricity built up on a technician's body, especially in dry parts of the country or during the low humidity of winter. The electrical charge builds to several thousand volts but the technician is unaware because the current is so low. The charges, however, can puncture thin layers of semiconductor material on circuit cards inside.

When installing or removing an LRU (line replaceable unit) check if it has an ESD warning label, as shown in the illustration. Here are some precautions:

If you're handling an LRU with its connector removed, don't touch the bare pins. Also, first touch the metal case (ground)---to drain off charges that accumulate on your body.

Before transporting an ESD-sensitive radio back to the shop (or manufacturer) obtain a conductive cover and place it over the connector (as shown in the illustration).

Before you remove a circuit card from an LRU, use a wrist strap that connects you to ground (the airframe). Place the card in a conductive bag made for the purpose.

The ESD problem could worsen as more components are squeezed into smaller spaces. There is also a trend to build larger circuit cards to accommodate integrated modular avionics on new aircraft. (A single module can cost the equivalent of four years of a technician's annual salary!) These simple grounding techniques, however, prevent damage.

Cooling

The greatest threat to the life of avionics is overheating.

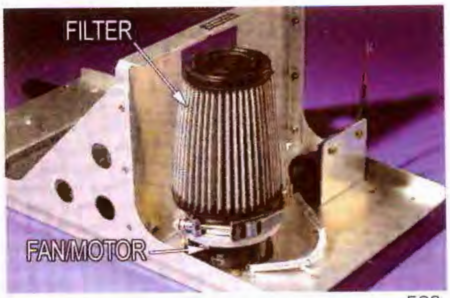
The heating problem grows worse as more systems are installed in limited space and the number of circuit components per square inch rises. Few people realized the full impact of temperature until military investigators in the 1960's proved that overheating was the number one cause of avionics failure.

There are several solutions to cooling. If the aircraft is air transport or military, cooling systems are carefully designed at the airframe manufacturer. As shown by the illustration, cooling for B-737 avionics is built in as part of the airplane.

Holes in bottom of ARINC-type tray admit air to cool avionics.

In General Aviation, there is no standardization because light aircraft vary widely in how they're outfitted. There is little official guidance so the solution is left to the installer.

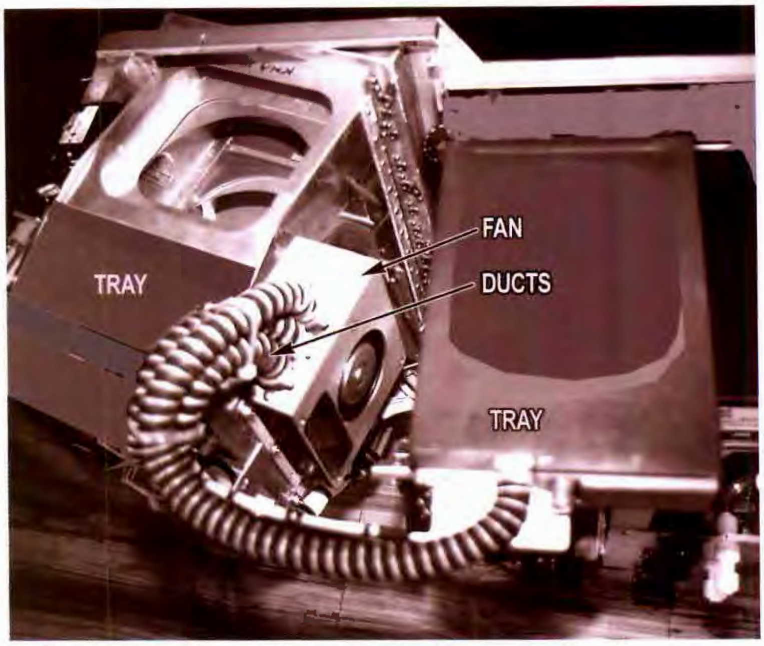
Some single-engine airplanes come from the factory with small air scoops on the fuselage where they catch the air blast from the propellor. It's the technician's responsibility to hook the air ducts from the scoops to the avionics. Some technicians believe the scoops also deliver water to the radios when flying in rain. This has never been proven and, after flying an airplane with scoops for many years, personal experience shows no bad effects on the radios. It is more prudent, however, to cool every avionics installation with forced air from one or more fans. Check to see if any piece of avionics has already been fitted with an internal fan and what the manufacturer says about ducting the air flow. When the short life of overheated avionics is explained to a pilot or owner, he invariably will want to pay for adequate cooling.



ECS

Cooling fan is built into ARINC tray for some airline avionics. A filter removes particles to extend equipment life and raise MTBF (mean time between failure).

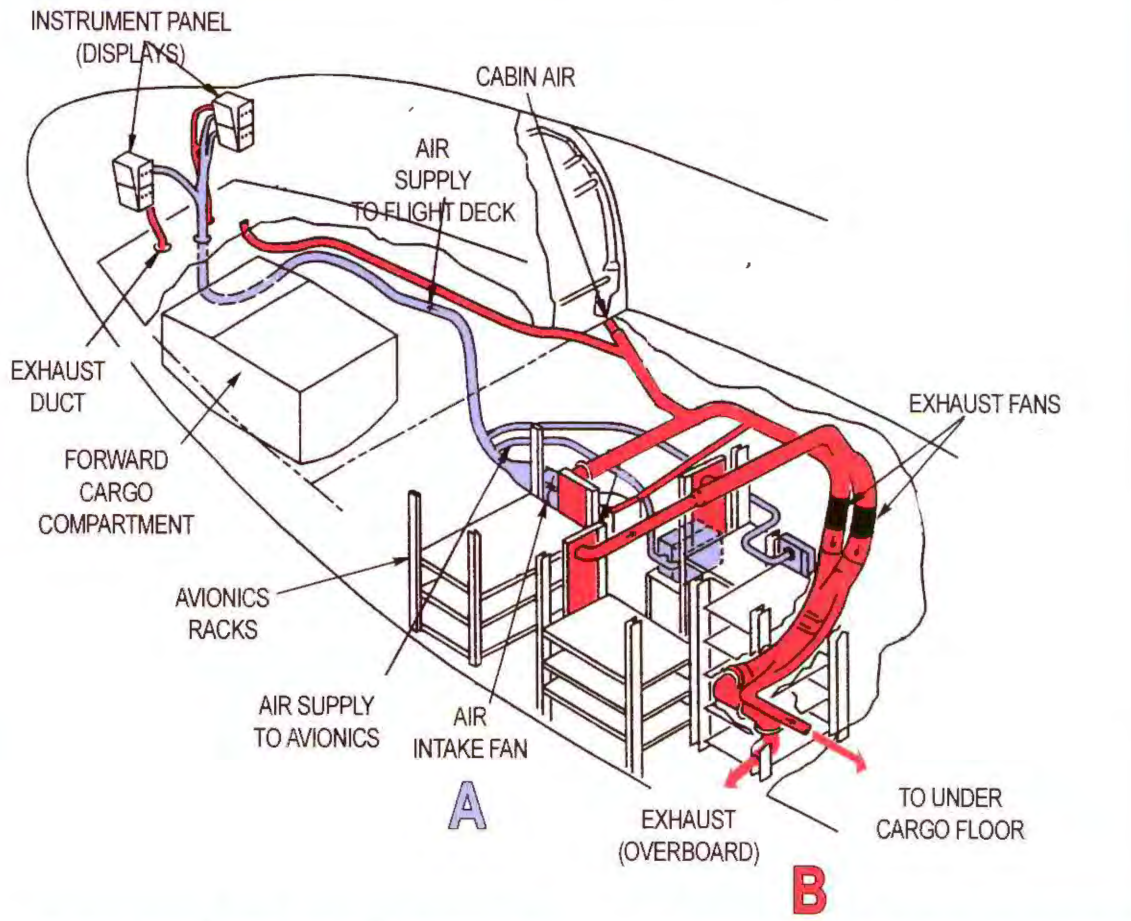
Warranty Warnings. A turning point in cooling happened when radios started using digital electronics. Some manufacturers will not honor the warranty if the radio shows signs of overheating (meaning it was installed without cooling). In earlier radios, warranty repair might be replacing a ten-cent resistor. The new radios, however, are loaded with integrated chips that are expensive to replace. In some instances, a whole circuit board is required, an expense the manufacturer wants to avoid.



Behind the instrument panel of a light aircraft, showing cooling fan and ducts. The fan is attached to the side of the radio stack at the left. Several air ducts are seen emerging from the fan. They connect to ports on the radio trays, where they deliver cool air.

Newer radios make the job of cooling much easier. They are often designed with nozzles for fastening air ducts leading to fans located some distance away. As shown, one fan may be rated to cool several radios.

Cooling for Airline Avionics



Air transport aircraft have dedicated systems for cooling avionics, as shown in this simplified diagram (based on a B-737). To assure reliability, both sides of the system---intake and exhaust---have two fans each. If one fan fails, an alarm warns the pilot to switch to the alternate.

In the illustration, blue ducts supply cool air, red ducts carry hot exhaust air from the equipment. The operation begins at "A - Air Intake Fan." The arrow points to a fan that draws air from the avionics equipment compartment. Cool air is supplied to some avionics racks through small blue ducts.

A large duct runs up to the flight deck and cools the instrument panel (mainly EFIS displays). Other equipment is cooled by air drawn through the avionics rack by an exhaust fan, and vented overboard or into the cargo compartment (see "B").

Hot air is vented overboard only when the airplane is on the ground or at low altitude. At higher (colder) altitudes, that air is sent to warm the forward cargo compartment.

Fans. Choose a cooling fan designed for avionics. To be sure, look at the catalog description; it should say PMA and TSO (Parts Manufacturers Authorization and Technical Standard Order---both FAA certifications.) They have brushless DC motors (which eliminate sparking and interference) and are 14- or 28-volt DC.

Fans are typically made with 1 to 5 outlets (or ports) which connect to radios through 5/8-inch hoses. If a fan has more ports than you need, unused ones are capped (which increases air flow to the other ports). Ample air is delivered, regardless of how many ports are connected. One port can typically put out about 26 CFM (cubic feet per minute) to cool one radio, such as a navcom or GPS.

Some fans come in kits, including mounting brackets and hoses. The manufacturer may also have a fan designed for a specific-model radio.

The fan is usually mounted near the rear of the radio stack and, in the simplest arrangement, hoses are brought near and aimed at the rear of the radio. Avionics of more recent design have a fitting for directly attaching the hose. In some installations, the hose attaches to a plenum, which is a metal chamber that runs alongside the radio stack, with holes that direct air to the radios.

An avionics fan may be expected to have long life, with ratings of nearly 80,000 hours of continuous operation.

Locking Radios in Racks

It not unusual for a pilot to taxi up to the radio shop and say; "My navcom doesn't work---no transmit, no receive." Before the technician reaches for any tools, he takes the palm of his hand and presses it against the face of the radio. The radio starts playing! The pilot is amazed. A large number of failures are simply due to vibration causing a radio to slide out of its connectors. Just a fraction of an inch does it. The remedy is to check the security of all radios when the airplane is brought to the shop.

Large aircraft have more effective locking devices, but even here there are problems if a radio is forced into its mounting tray. Designers in recent years have produced sturdier trays which resist bending and deforming. The latest approach is known as "zero insertion force," where the technician doesn't push the radio home. He operates a lever that causes the connectors to mate. This development followed a great increase in the number of terminals within a single connector, which increases chances of mis-mating pins and sockets by forcing the radio into the tray.

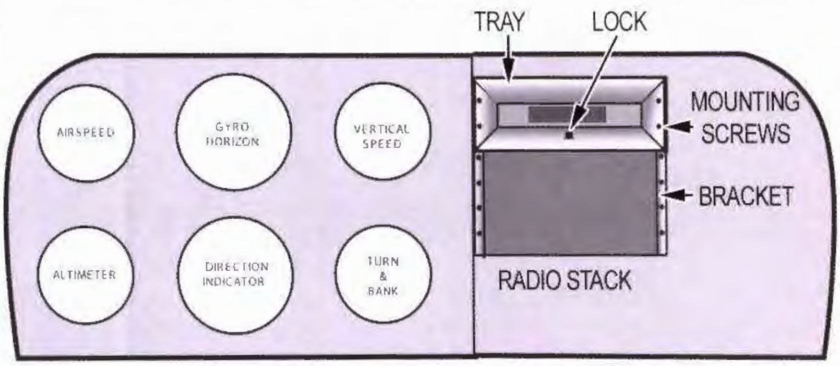
Panel-Mounted Radios

In the Instrument Panel

Avionics that mount in a panel are usually retained with a latch operated by a tool inserted into a hole in the front of the radio. Commonly used tools are an Allen wrench, size 5/64 or 3/32.

When the radio is installed, the latch is first positioned correctly by turning the screw all the way counterclockwise. Look at the underside of the radio and there should be a notch (or cut-out) which receives the latch. After the radio is slid into the rack, the latch should be aligned with the cut-out. Turn the wrench just enough to feel the latch engaging

Next, be sure the connectors at the back of the



INSTRUMENT PANEL

Although panel-mount radios are associated with small aircraft, they're also found in commercial aircraft (commuter and regional airlines). The panel mount uses the instrument panel as the support structure. A rectangular hole is cut in the panel and vertical brackets riveted to the sides of the opening. The tray (which receives the radio) is bolted to the brackets. After the tray is mounted, the radio is slid in and locked by turning a front panel screw, as shown.

After radios are mounted , they may be too heavy to be supported by the instrument panel. In this event, the installer adds brackets from the *back* of the radio trays to the airframe.

RADIO STACK

Releasing the Radio

Typical radio stack in a light aircraft. In this example, there are two navcoms at the top, with a transponder on the bottom. They slide into trays which are fastened behind the instrument panel. The usual method for inserting or removing these radios is inserting a tool (Allen wrench, Torx, screwdriver or other) at the lock release points.

radio and on the tray are ready to engage.

While you turn the wrench clockwise, place a hand on the radio front panel and gently push to help the radio into the connectors. In other words, don't just depend on the latch to draw the radio in.

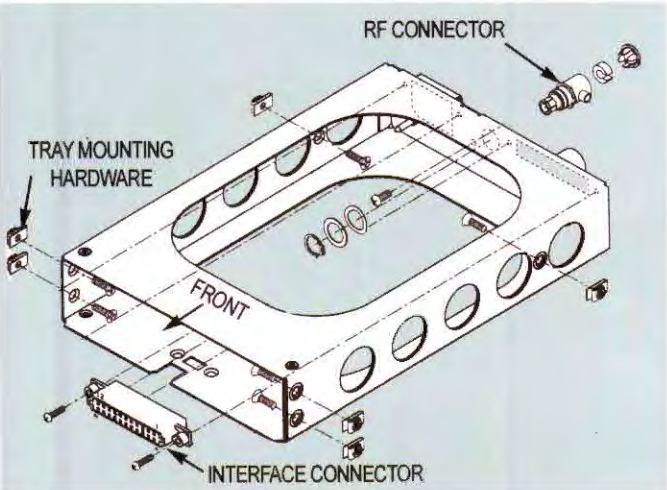
Be gentle with the final tightening. With the radio completely in the rack, tighten the screw only to snug up the radio to the back of the tray. Tighten too much and the latching mechanism can be damaged.

If you're installing a stack of radios vertically, sometimes one opening is too narrow and blocks a last radio. You can usually solve this by loosening all the radios in the stack and sliding them back in a different sequence.

Instead of Allen wrenches, some radios use an ordinary slotted screw. Often they require only a quarter-turn to engage or release. If the radio will not release, hold the front panel at the sides and try to work it out with a slight sidewise motion.

Some radios require a very long screwdriver with a 1/8-inch flat tip to operate the locking mechanism. Others require a special tool inserted through the front to activate a release device.

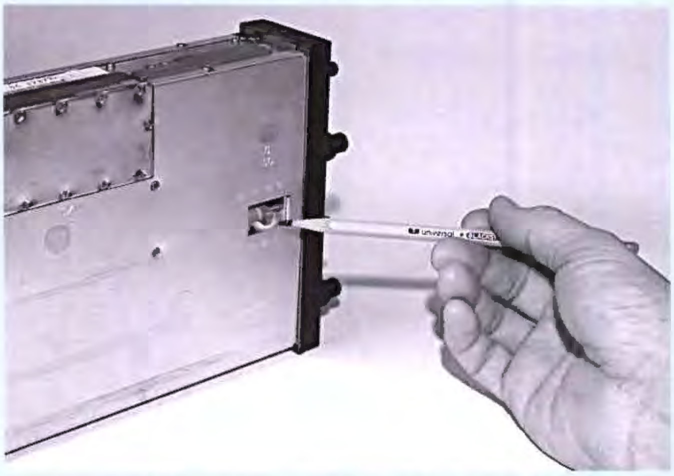
Regardless of the system for locking the radio to its tray, the rule is: don't force it. If something is stuck (a frequent problem with old radios) try to coax, rock, wiggle or gently pry until you find a path of least resistance out of the rack.



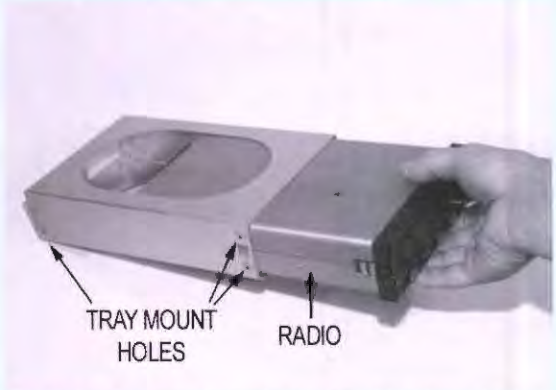
Preparing the tray for mounting. Hardware on the sides of the tray holds it to brackets in the instrument panel. The RF connector, which goes to an antenna, is fastened at the back. The interface connector will also mount on the rear of the tray, next to the RF connector. Holes along the sides of the tray lighten the structure.

Panel-Mount Details

A panel-mounted radio is removed from the instrument panel by inserting a tool into an opening on the front. It may be a screwdriver, hex wrench or other tool.

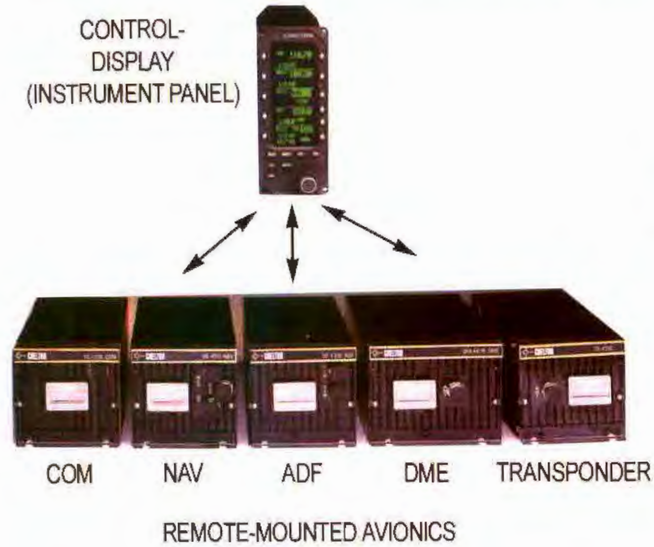


Pencil points to locking mechanism at underside of radio. As it turns, it engages a slot in the tray and pulls the radio in. To avoid damage, never force the radio into the tray.



Radio is shown sliding into mounting tray. Holes in the tray are for fastening the tray to the instrument panel.

Remote-Mounted Radios (Corporate)



In remote-mounted avionics, only a control-display unit (CDU) is in the instrument panel; the rest is in a remote location. For small business aircraft, the location is often in the nose; larger jets have a compartment in the fuselage.

The reason for remote mounting originally was that radios were too large to fit behind the panel. With microminiaturization, however, avionics are now often less than half their original size.

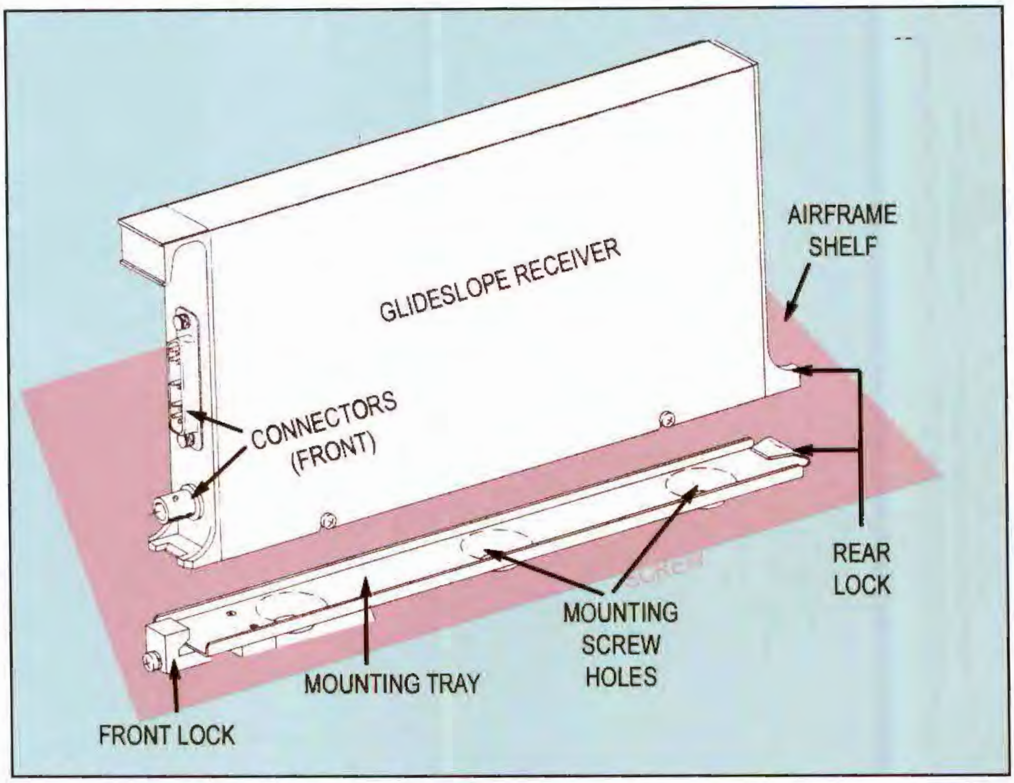
The example in the illustration is a Chelton radio management system. The small control-display manages the large remote boxes (LRU's, or line replaceable units).

Mounting Tray

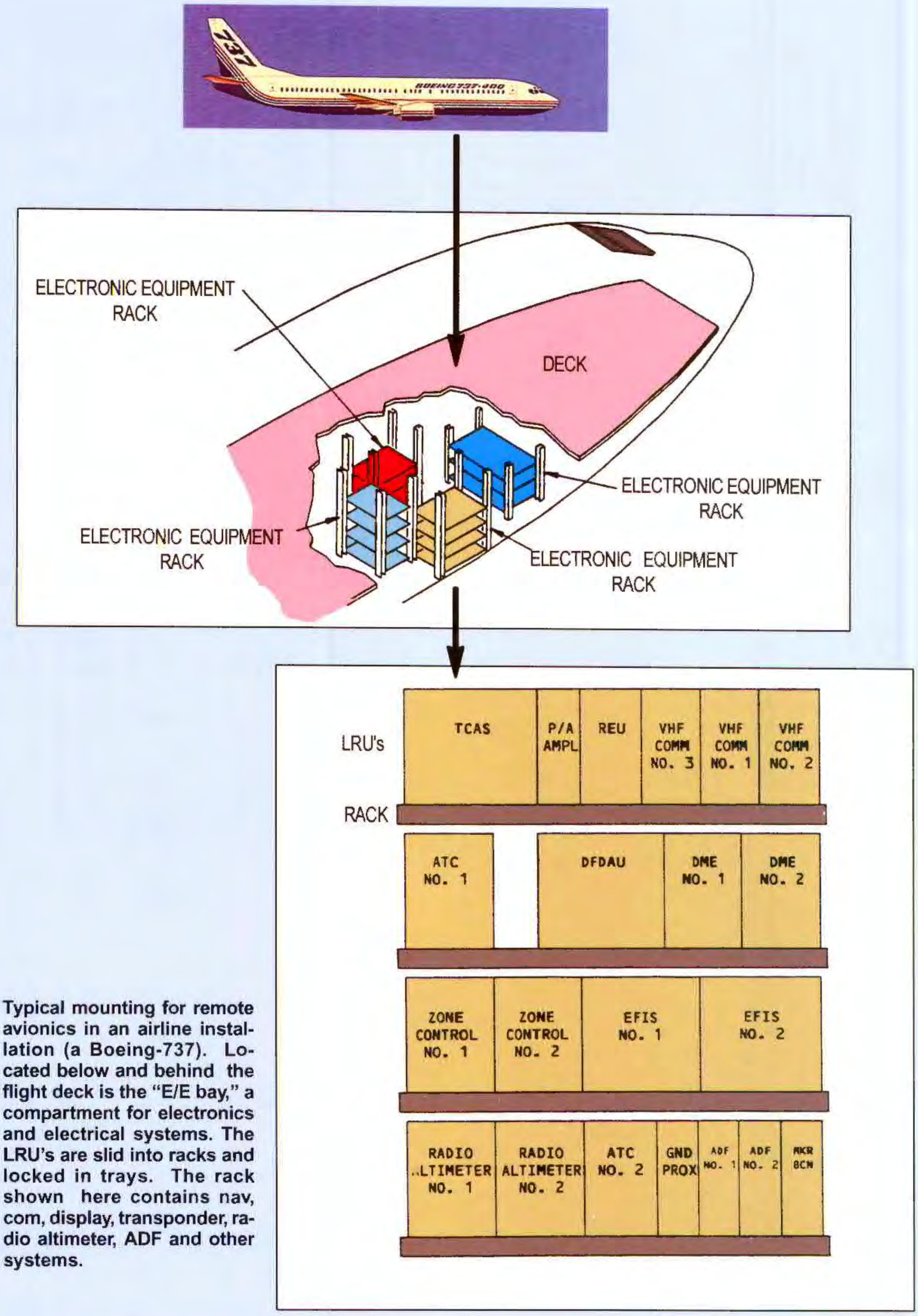
The remote radio is supported in a tray located away from the flight deck. (Shown in this example is a Collins glideslope receiver.) At the bottom, the tray is fastened to the airframe by screws. That structure can be a shelf fabricated by the technician or one that already exists in the airplane.

After the tray is in place, the radio slides in and engages the rear lock. The front lock is tightened to complete the installation.

Connectors on the front of the radio go to the control head in the instrument panel, a power source and the glideslope antenna.

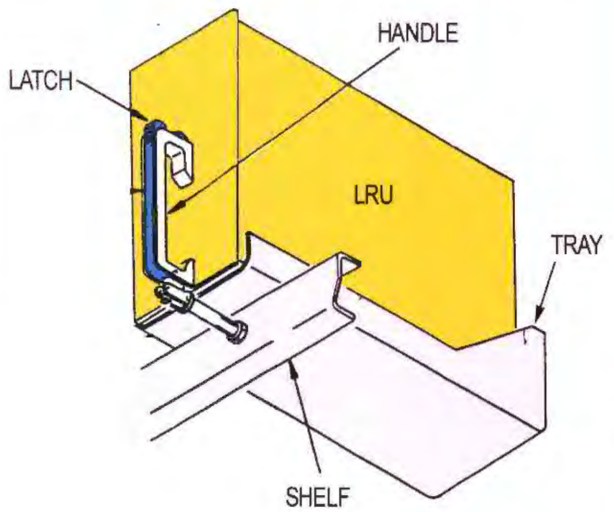


Airline Mounting

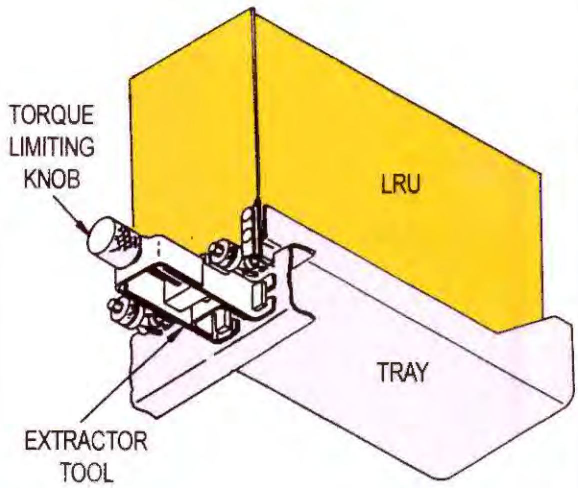


Typical mounting for remote avionics in an airline installation (a Boeing-737). Located below and behind the flight deck is the "E/E bay," a compartment for electronics and electrical systems. The LRU's are slid into racks and locked in trays. The rack shown here contains nav, com, display, transponder, radio altimeter, ADF and other systems.

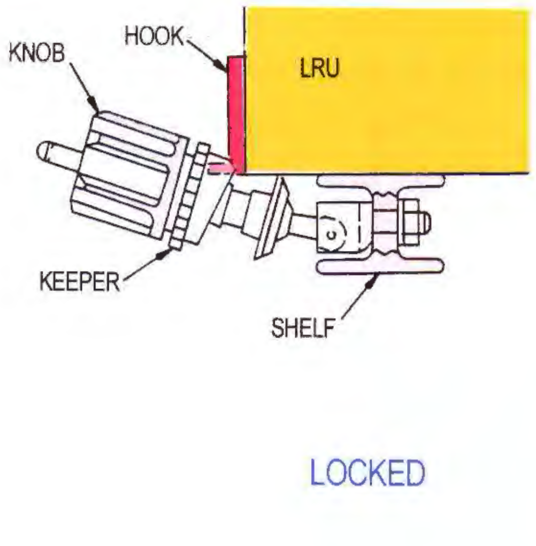
Locking Systems (Airline)

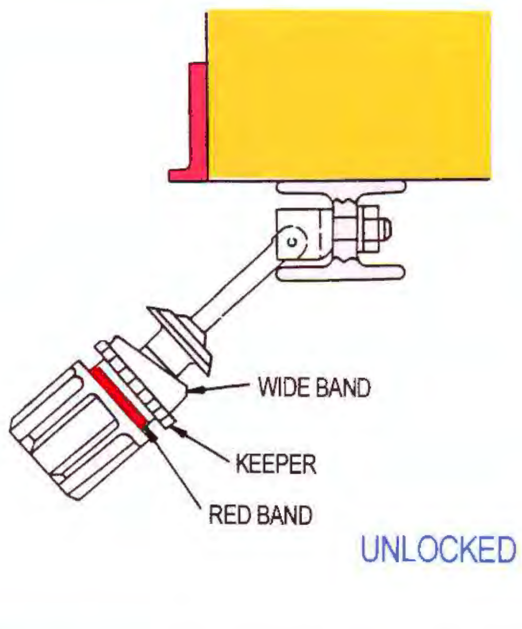


Three different hold-down systems are shown. Above is a cam-lock lever arrangement in the locked position. Pulling down the handle releases the LRU from the tray.



A knob and extractor tool release the LRU. To prevent damage from overtightening by the technician, the thumbscrew slips after proper torque is reached.

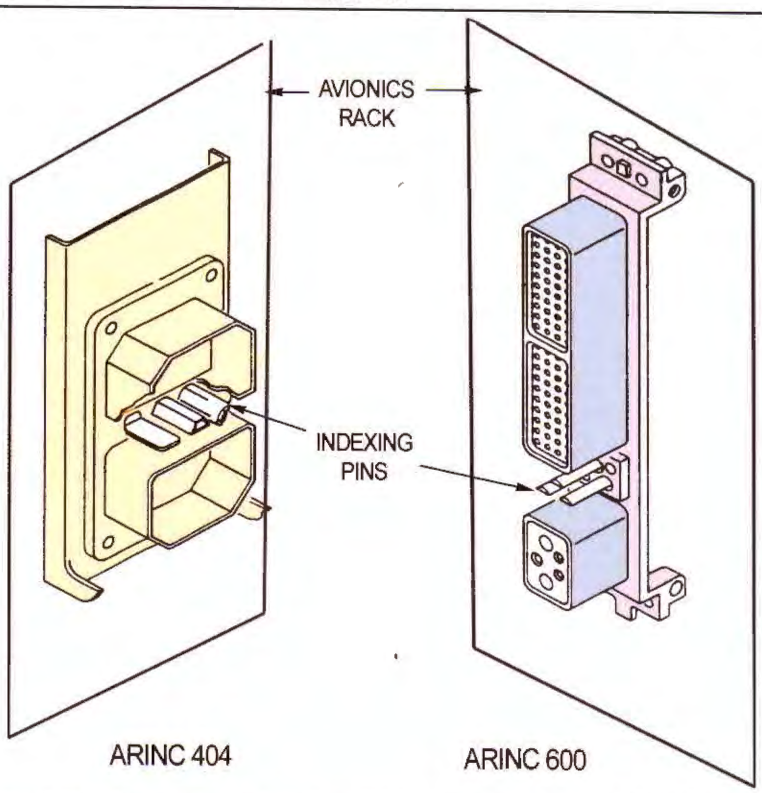




In this hold-down system, tightening the knob engages a hook. The system is shown in the locked position

Shown here is the unlocked position. The "Wideband" and "Red Band" fittings help the technician align the locking system before tightening.

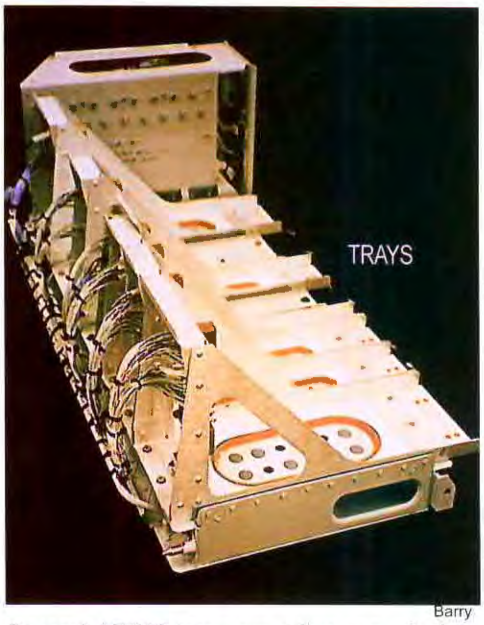
Indexing Pins Prevent Error



Different avionic LRU's (line replaceable units) are often housed in cabinets of the same size---which could cause installation error. To prevent it, a connector has an indexing pin at an angle that matches only one LRU. Unless all pins line up with connector holes, the radio cannot be pushed in. To prevent damage, however, avoid forcing a radio into the rack.

US Technical

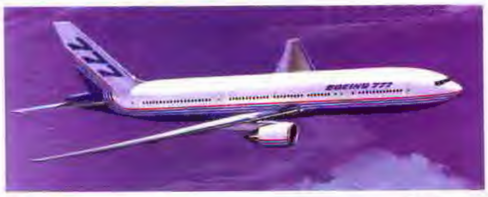
ARINC trays are designed with variations to accommodate different cooling, connector and radio sizes. The black knobs, which lock in the equipment, have a mechanism which cannot be overtightened and damage the connectors.



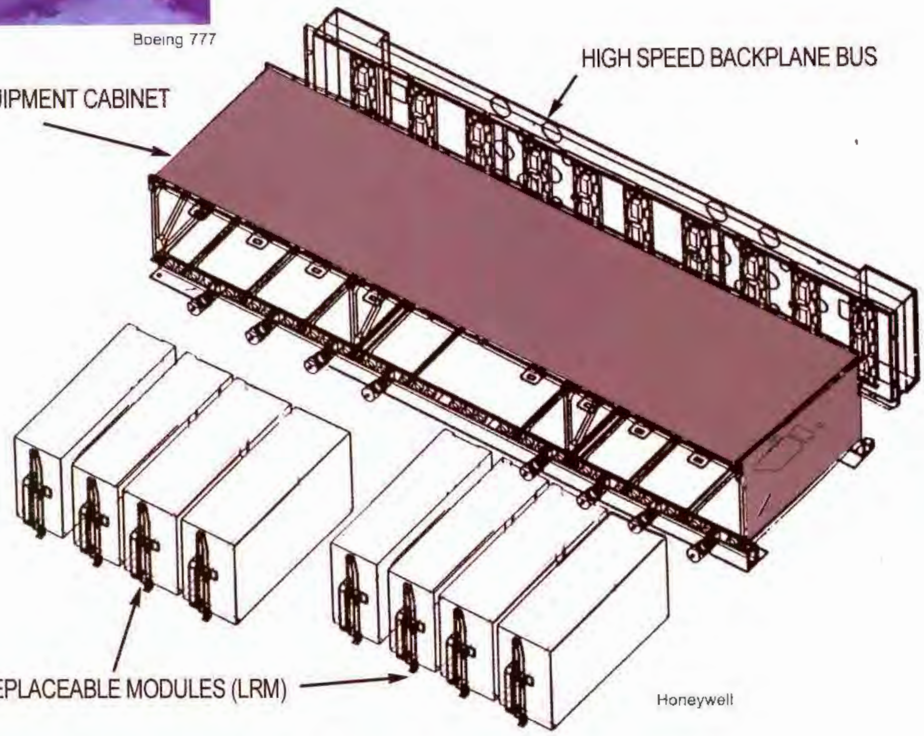
Barry

Several ARINC trays are often mounted together to form a "rack" (sometimes called an "equipment cabinet").

Integrated Modular Avionics (IMA)



Boeing 777



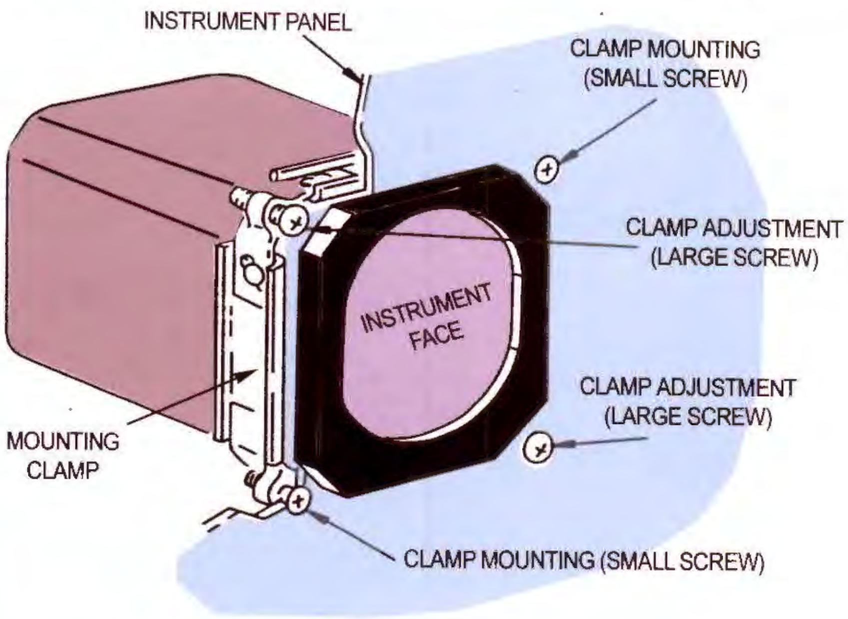
Honeywell

Integrated Modular Avionics (IMA) replace separate LRU's (line replaceable units), with LRM'S, "line replaceable modules." Unlike earlier systems, LRM's do not have one function per unit, such as receiver, transmitter, etc. They are more like computer resources that share and process information over a high speed databus. This provides smaller size and weight, and greater reliability.

For the technician, troubleshooting is simplified by a built-in central maintenance computer that identifies problems and indicates which module to replace.

Example of a cabinet for Integrated Modular Avionics. Red handle is used to unlock and remove the Line Replaceable Module (LRM)

Instrument Mounting

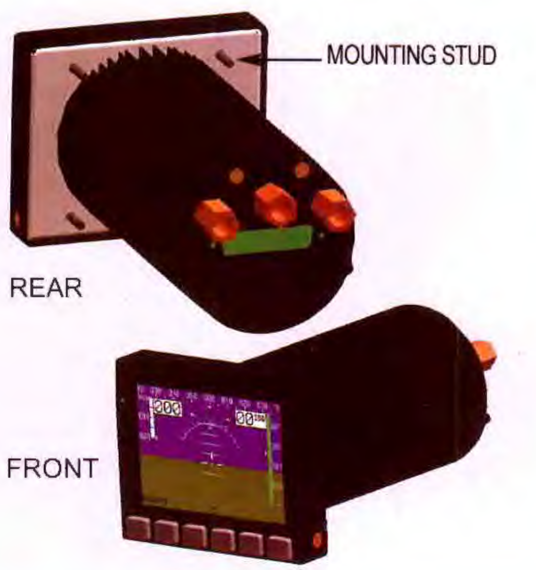


Instruments like this 3-inch rectangular are often held by a mounting clamp behind the panel. The clamp is slid over the case and two sets of screws are adjusted. Two screws have large heads labelled "Clamp Adjustment". They tighten the clamp around the case. The other pair, labelled "Clamp Mounting," hold the clamp to the back of the instrument panel.

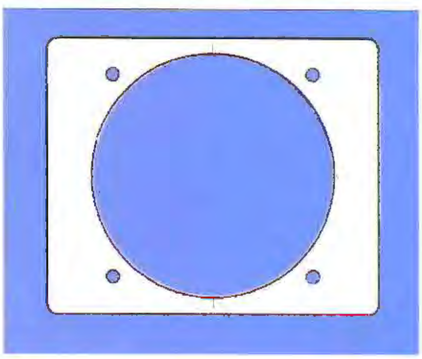
Round instruments are installed in similar fashion with a round clamp. However, there are only two screws; one to tighten the clamp on the instrument, the other to hold the clamp to the panel.

Some instruments have tapped holes on their cases and need no clamps. Check the manufacturer's literature on using the correct screws. If too long, they can penetrate the case and damage the instrument,

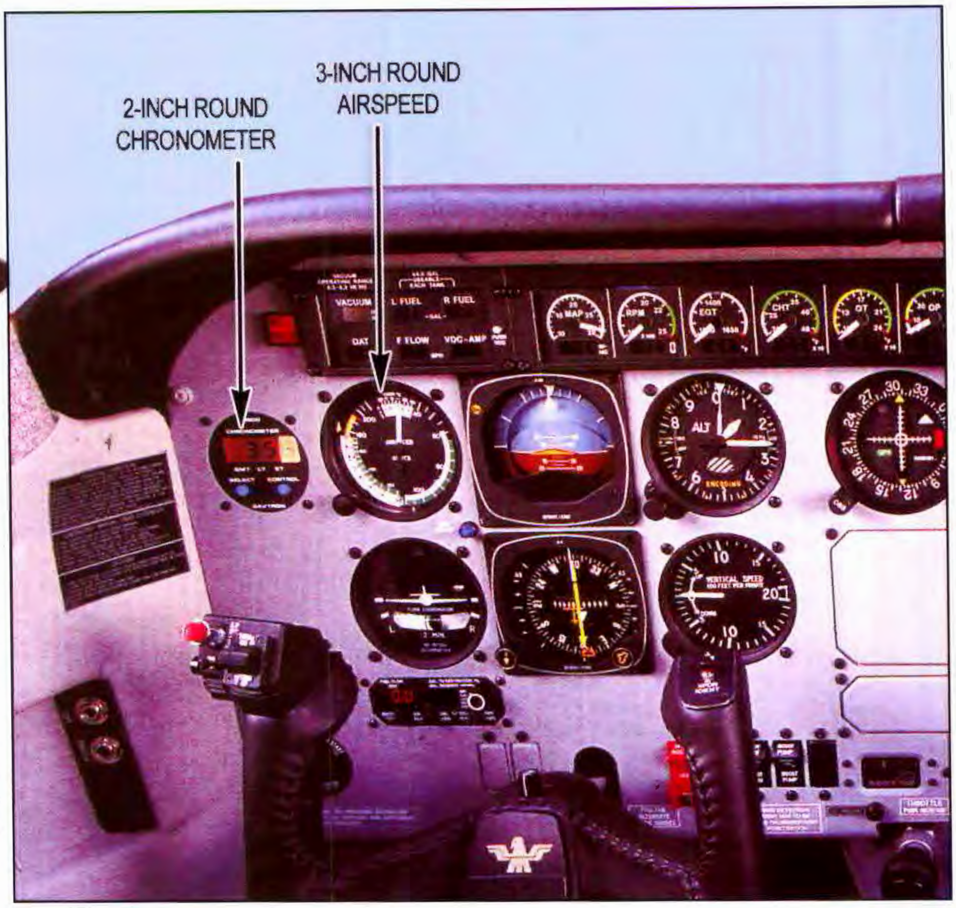
Instrument screws are often made of brass, especially when mounting a magnetic compass. As a non-magnetic metal, brass will not cause deviation in the compass.



Some instrument cases are fitted with mounting studs, as in this Dynon EFIS display. Four holes are drilled in the instrument panel according to the template (below) supplied by the manufacturer. The large hole receives the instrument case.



Round Instruments: 2- and 3-inch

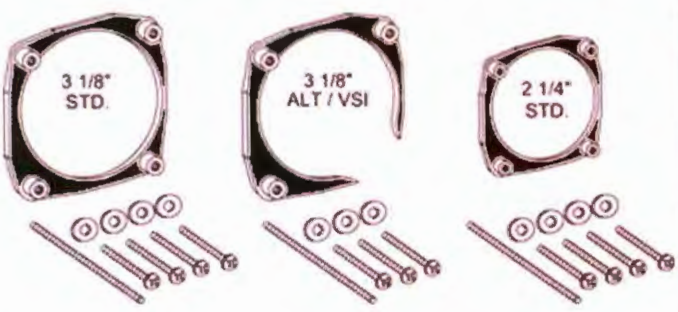


Many flight instruments in General Aviation mount in round holes. The two main sizes are 2- and 3-inch diameters (actually 2-1/4 and 3-1/8-inches).

An example of each is shown in this Mooney panel; a 2-inch chronometer and a 3-inch airspeed indicator.

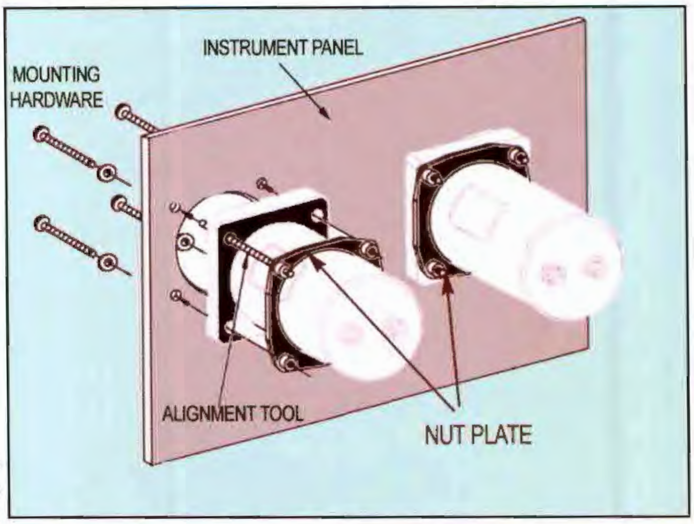
The instruments are held to the panel by four screws, as seen around the instrument face. The screws are held behind the panel by threaded fasteners ("grasshopper nuts"). Because the fasteners are easily lost during installation, there are mounting kits like the one shown below to simplify the job.

Instrument Mounting Kit



Edmo

"Nut rings" make the installation job easier. They come in standard 2- and 3-inch sizes. There are two versions of the 3-inch; note the one in the center, "ALT/VSI" which has a cut-out at the lower right. This allows space for the altimeter knob after the instrument is installed. ALT is for altimeter, which has a knob adjusted by the pilot (for barometer setting). VSI (vertical speed indicator) has a small screw adjustment for zero'ing the needle.



A nut plate is installed by sliding it onto the back of the instrument. To make it match holes in the panel with holes in the nut plate, the installer inserts an alignment tool through one hole, as shown. It's removed when all holes line up, and mounting screws can be inserted.

Airline Instrument Mounting

Instruments designed for the panel of airliners have case sizes that conform to "ATI" dimensions. Developed by ARINC, they assure the instruments will match holes in the panel.

Generally, a "3 ATI" instrument is approximately 3 inches wide, a "4 ATI" is 4 inches wide (but check the manufacturer's information for exact dimensions).

An example is the instrument pictured above; a VSI-TCAS (vertical speed and anti-collision display). It is offered by the manufacturer (Sextant) in either a 3 ATI or 4 ATI size. Because ATI instruments have bevelled (slanted) edges, it is difficult to make the cut-out with ordinary hand tools. Special cutters are available.

Although ATI sizes are an airline specification, they are also found in corporate and light aircraft, as well.

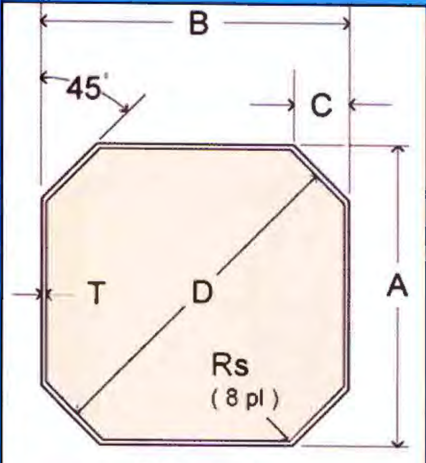


Figure 1

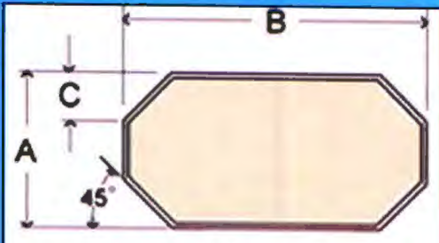


Figure 2

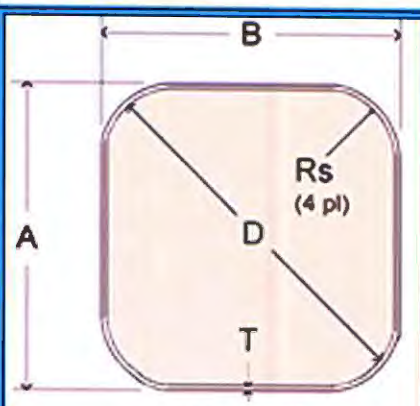


Figure 3

ARINC 408
Instrument Housings

ATI SIZE	A	B	C	D	E	Rs	FIG.
	± .010	± .010	REF	± .010	± .010	REF.	
1.5 X 3 ATI	1.457	3.175	0.428	2.67	2.775	0.125	2
MM	37	80.84	10.87	67.81	69.97	3.17	2
1.5 X 4 ATI	1.457	3.975	0.428	3.236	3.321	0.125	2
MM	37	100.96	10.87	82.19	84.35	3.17	2
2 ATI	2.175	2.175	0.407	2.5	2.585	.063, .695	1 & 3
MM	55.24	55.24	10.33	63.5	65.65	1.6, 17.653	1 & 3
2 X 4 ATI	2.175	3.975	0.407	3.773	3.858	0.063	2
MM	55.24	100.96	10.33	95.83	97.99	1.6	2
3 ATI	3.175	3.175	0.428	3.885	3.97	.063, .725	1 & 3
MM	80.64	80.64	10.87	98.67	100.83	1.6, 18.415	1 & 3
3 X 4 ATI	3.175	3.975	0.428	4.451	4.536	0.063	2
MM	80.64	100.96	10.87	113.05	115.21	1.6	2
4 ATI	3.975	3.975	0.429	5.015	5.1	0.063	1 & 3
MM	100.96	100.96	10.89	127.38	129.54	1.6	1 & 3
4 X 5 ATI	3.975	4.975	0.429	5.722	5.737	0.068	2
MM	100.96	126.36	10.89	145.33	145.71	1.6	2
5 ATI	4.975	4.975	0.478	6.36	6.445	0.063	2
MM	126.36	126.36	12.14	161.54	163.7	1.6	1
5 X 6 ATI	4.975	5.975	0.478	7.067	7.152	0.063	2
MM	126.36	151.76	12.14	179.5	181.66	1.60	2
6 ATI	5.975	5.975	0.513	7.725	7.81	0.063	1
MM	151.76	151.76	13.03	196.21	198.37	1.6	1

Review Questions
Chapter 23 Mounting Avionics

23.1 Who should be consulted if an avionics installation will affect structures in the airplane?

23.2 What designation assures that a piece of equipment has high resistance to heat, humidity and other environmental conditions of flight?

23.3 "Approved data" for an installation may be found in the ____________

23.4 When selecting aluminum for making structures, what label indicates resistance to corrosion?

23.5 What are efficient methods for cutting odd-shaped instrument holes in an aluminum panel?

23.6 When mounting new equipment in an instrument panel or in the avionics bay of a large aircraft, do not exceed the __________ and _________ limitations of the airplane.

23.7 What is a major advantage of ARINC cases in large aircraft?

23.8 What are the two basic types of ARINC cases?

23.9 What are two precautions when handling avionics that are sensitive to electrostatic discharge (static electricity)?

23.10 What is the greatest threat to the life of avionics?

23.11 What techniques are used in large and small aircraft to prevent overheating?

23.12 When mounting a magnetic compass, always use ________ screws to avoid___________in the compass.

Chapter 24

Connectors

Working with connectors often takes up more of an installation technician's time than any other task. A light aircraft has connectors in the dozens, while larger airplanes count them in the hundreds. Without connectors, avionics can't be removed for maintenance or modifications.

There is a trend in avionics to reduce the amount of connectors and wiring. They add weight, take up space and cause trouble when improperly installed. It is now possible to blend signals of many systems on a single pair of wires or fiber optic cable and send them around the airplane. Applications increase with each generation of new aircraft but we will have to live with connectors for another 30 or 40 years.

Connectors look like simple mechanical devices--

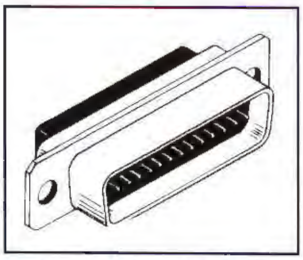
--an outer shell, terminals (pins or sockets) and insulating material. Nevertheless, connectors are a major cause of equipment failure. Pins are wired incorrectly, bare wires touch and short-circuit or connector pins are accidently bent. All can be avoided by careful wiring technique.

Technicians have different approaches to avoiding errors in wiring. Some follow the old carpenter's warning; "Measure twice, cut once." In wiring, it means double-checking for the correct pin, marking each pin on the diagram as it's done and making a final check after all wiring to the connector is complete. Finding trouble after the installation is done takes far more time than checking for error as you build up the wiring harness.

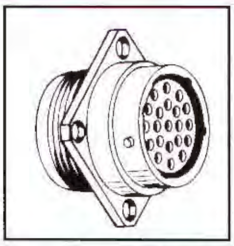
Reading pin connections. Some errors are due to the way pins are identified. Because of their high number and small size, markings on connectors are not only tiny, but often the same color as the background. You may have to hold the connector up to a bright light to make the number legible.

(continued p. 202)

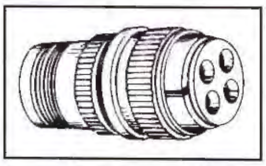
Typical Connectors



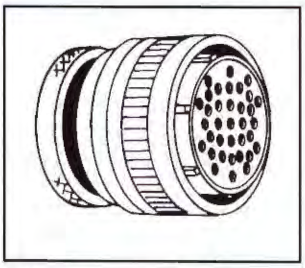
Rack and panel miniature rectangular connector.



Circular connector with bayonet coupling.

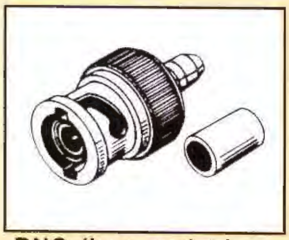


Circular connector with threaded coupling. Front release contacts.

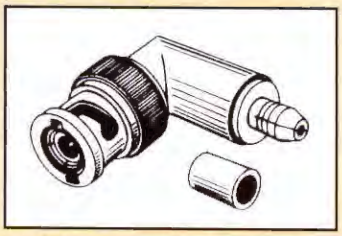


Circular connector, threaded coupling.

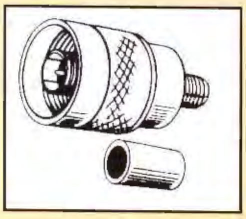
RF (Radio Frequency) Connectors



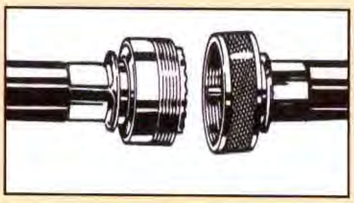
BNC (bayonet) plug



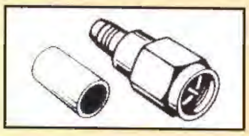
BNC plug with right angle



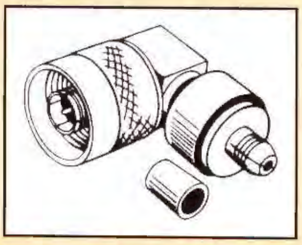
Series TNC plug, pin contact



Series N plug



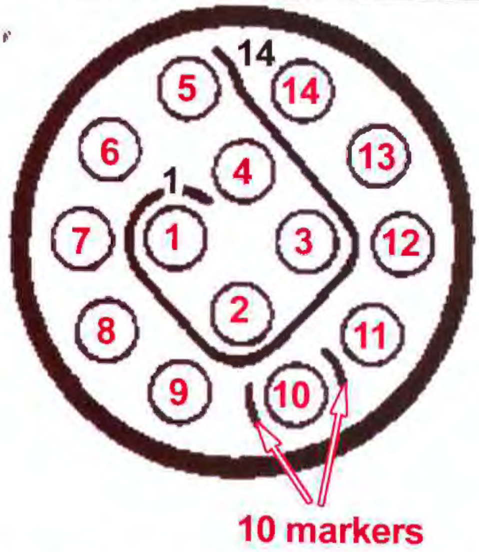
Series SMA plug, pin contact



Series TNC plug, right angle

How to Identify Connector Contacts

1. The end of a circular connector, where contacts will be inserted. Some connectors identify every contact, but limited space may allow only starting and ending numbers like "1" and "14," shown above. Start at "1" and follow the guide line around to "14," as shown by the arrows (which are not on the connector).



2. The same connector is shown; with red numbers added to clarify the numbering system. Note that "10" is surrounded by two markers. They speed up your counting. You can jump to the first marker and know it's 10. When looking at the back of a connector (where the terminals are inserted or wired) counting is usually done in a counterclockwise direction.

Contacts are Selected to Fit the Application

A circular connector, like this RMS bayonet receptacle, can be obtained with a variety of contacts (pins and sockets) to fit the application.

Shown below is an excerpt from an RMS specification sheet. By knowing maximum current rating and wire size, you can order the contact size for insertion into the connector. The contacts in this model are rear insertion and front release.

Contacts

For use with Series R0715, R0716, R0717, R0718 and R0719

Contact Size	Wire Size AWG	Max. Current Rating Amps.	MS Part No.	
			Pin	Socket
No. 20	24 22 20	3.0 5.0 7.5	M39029/31-241	M39029/32-260
No. 16	18 16	16 22	M39029/31-229	M39029/32-248
No. 12	14 12	32 41	M39029/31-235	M39029/32-254

Several examples of how letters and numbers identify pins are shown in the illustrations. Some use numbers, such as 1 through 15 or 1 through 34. Others use letters A through Z. If the total number of connections goes beyond Z, the next pin may be "a" or "aa" (lower case letters).

Caution: Some connectors omit letters such as G, I, O and Q. Therefore, don't simply count the pins to get to a desired one unless you are sure the numbers or letters are consecutive.

Soldering Connectors. The classic method for attaching a wire to a connector terminal is with a soldering iron. It is a more difficult skill than it appears. A soldering iron in tight spaces with small objects easily causes heat damage. Also, many beginners believe that solder is "pasted" onto a wire by dabbing it with the iron. This results in a "cold solder joint" which soon crumbles. Good soldering technique requires that the iron heats both wire and terminal so solder turns liquid and flows freely between them. The technique has proven troublesome enough for airlines and military organizations to run "soldering schools," taught by a skilled operator (often from a manufacturer of soldering tools).

Now the good news; soldering wires to connectors has been largely replaced by a faster, more convenient and effective joining method.

Crimping. This is the process of squeezing a metal contact around a wire with a special tool. As shown in the illustrations, the wired contact is then inserted into the connector until it snaps into place. You *must* have the crimping tool designed for that size and type of terminal. A good crimping tool has a mechanism which applies the correct force to crimp the terminal no matter how hard you squeeze the handles.

Back shell. Some connectors have a back cover, or shell, which protects the wire where it enters the connector. The back shell may also have a clamp that goes around the wire bundle to relieve strain on the pins. Strain relief for all wires entering a connector is important. If there is stress from a wire pulling on its terminal, the connection may not last long.

Connector Trends

Aviation borrows heavily from connectors for the computer industry (similar to those on the back of a PC). They accommodate large numbers of wires, and provide reliable, fast methods of attaching connections.

(Continued p. 206)

Identifying Mil-Spec Connector Part Numbers

Many connectors in avionics comply with a Military Specification. Using the "MS" number, you can decode the connector's specifications. Consider the example (by Glenair):

MS3402DS28-21 PY

MS =	Military Standard
3402 =	Box Mount Receptacle (Designation)
D =	High Shock (Environmental)
	Shell Material
28 =	Shell Size
21 =	Contact Arrangement
P =	Pin type (Male)
	or "S" (Socket, or female)
	Polarization keying

The first four numbers after "MS" (3402 in the example above) indicate physical type. Other types include:

3400	Wall mounted receptacle
3401	In line receptacle
3402	Box mount receptacle
3404	Jam nut receptacle
3406	Straight plug
3408	909 plug
3409	45Q plug
3412	Box mount receptacle with rear threads

The single character which follows indicates the connector service class:

D	High Shock
K	Firewall
L	High Temperature
W	General Purpose

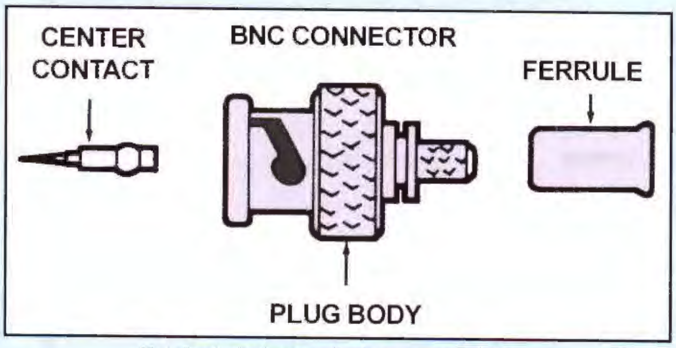
The next character, S in our example, indicates the shell material; in this case, stainless steel.

The next two characters, 28, identify the shell size.

The following pair of numbers, 21, identifies the contact arrangement. If this pair of characters is followed by an "S", it indicates female style (socket) contacts. If they are followed by a "P", it indicates male contacts (Pin).

The final character, Y, indicates the choice of polarization keying.

Typical Coaxial (RF) Connectors

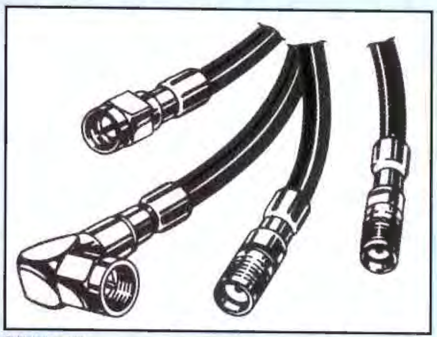


Exploded view of plug assembly

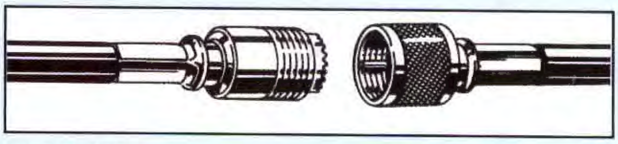
BNC
This is among the most common RF connectors for avionics. A bayonet coupling makes it easy to make or break the connection with a push and half-twist. BNC's are typically rated for 50-ohm coaxial cable.

TNC
This is similar to BNC but replaces the bayonet with a threaded coupling. The TNC is a higher-performance connector, especially under high vibration.

Both BNC and TNC connectors come in a variety of mounting styles, including bulkhead, straight and right angle.



SMA SERIES
Widely used in avionics, especially for military applications. It's a high performance connector for subminiature coaxial cable.

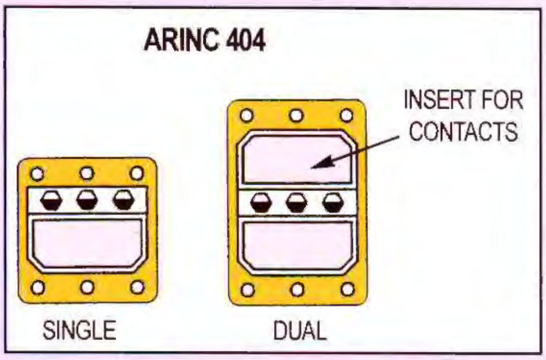


N SERIES
A screw-on connector, the N type is available for crimp connection to coaxial cable.

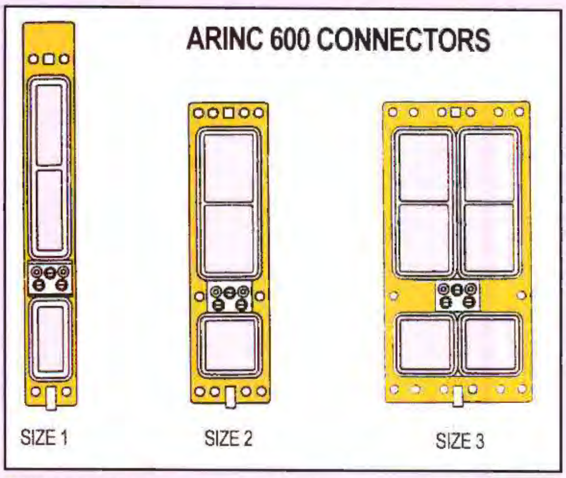
Connector Illustrations: Anixter

ARINC Connectors (Airline)

ARINC, the airline avionics organization, sets the standards for connectors aboard nearly every airline in the world. The two most common series are ARINC 404 and ARINC 600.



ARINC 404 is aboard airliners that began production during the 1960's. This includes first models of the Boeing-727, -737, -747 and Airbus-300. Instruments and radios operate on conventional (analog) principles, which require fewer pins than today's avionics. These connectors are set up for various equipment by different inserts (which hold the contacts). The ARINC 404 connector is still needed on most recent airliners.



ARINC 600 appeared with the new generation of "digital" airliners during the 1980's, including the Boeing-757, -767 and Airbus A-320. Because of the advanced systems, ARINC 600 provides more contacts in a small area

When old airline aircraft are upgraded with digital avionics (such as the Boeing 747-400) the flight deck becomes a "glass cockpit, " meaning EFIS, the electronic flight instrument system. Digital equipment requires ARINC 600 connectors.

There are several methods for wiring a coaxial connector to a cable, including crimping and soldering. The method shown here uses a cable nut to squeeze together the connector parts. Regardless of method, follow the manufacturer's cutting dimensions carefully when trimming back the cable.

During the final step, 5, the cable nut is threaded into the connector body. This tightens the shield clamp over the shield for good electrical contact, and connector parts are tightly held together.

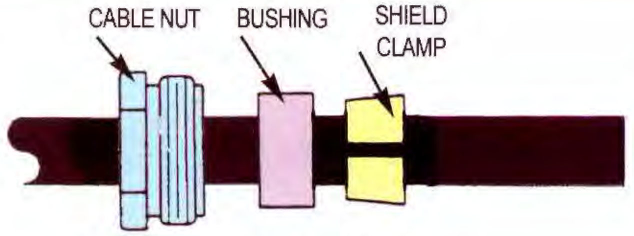
The solder hole is heated and solder added to connect the center conductor to the pin. Avoid overheating to avoid damage to the wire insulation.

Coaxial Connector: Attaching to Cable

1.

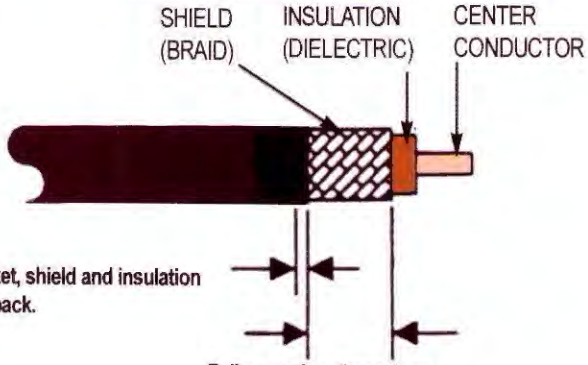
Coaxial cable is trimmed to the desired length. Cut the end of the cable squarely or it won't fit easily into the connector.

2.



Slide the hardware (cable nut, bushing and shield clamp) over the cable

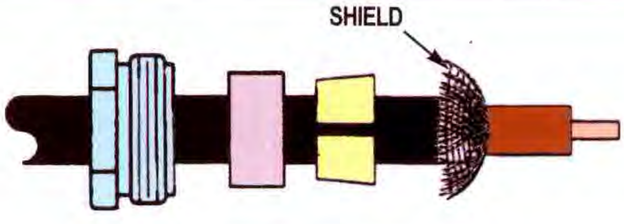
3.



The cable jacket, shield and insulation are trimmed back.

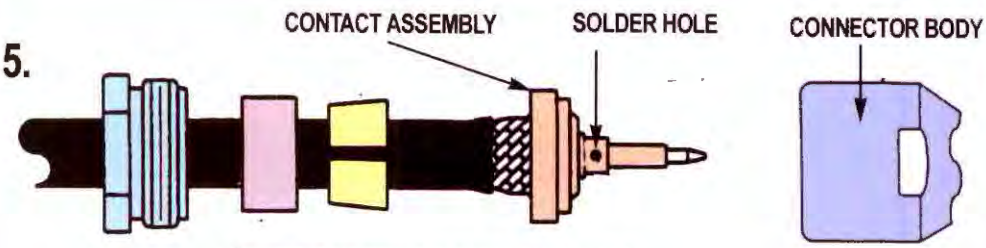
Follow cutting dimensions provided by the manufacturer

4.



Push the shield back over the cable jacket.

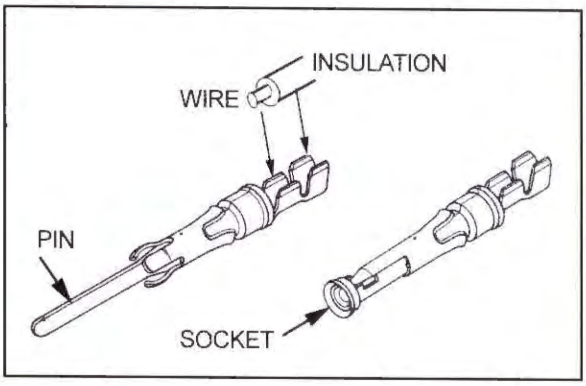
5.



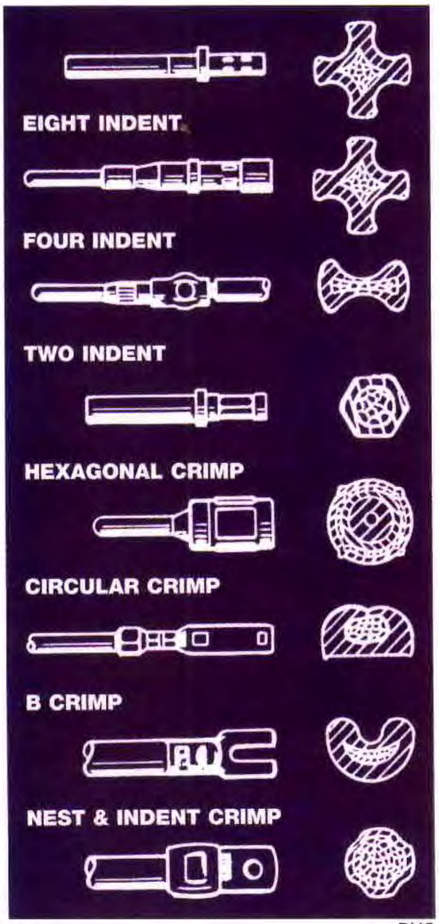
The contact assembly is pushed under the shield. Apply solder to the hole and heat just enough for solder to fuse with the wire and contact.

Crimping: Attaching Wires to Connector Contacts

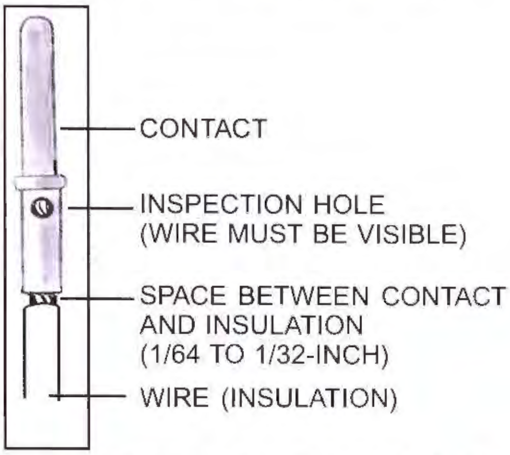
Connector contact (in red circle) is crimpled to the end of a wire with a crimping tool (type DMC AF8).



Pin and socket contacts that will be inserted into the connector. The wire is crimped into tabs on the contact. Another set of tabs clamps the insulation to relieve strain. These terminals are used in a "Molex" connector.



Crimp tools are fitted with dies for making different crimp patterns. The most common for avionics work is the "Eight Indent" shown at the top.



In this type of contact, there is an inspection hole. Bare wire must be visible through the hole. There must also be a small space between the contact and the insulation.

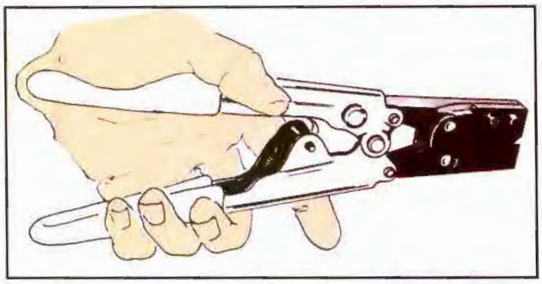
This crimp tool has wide application among miniature and sub-miniature connector types. It delivers a standard 8-impression crimp. When the handles are squeezed, a ratchet controls maximum pressure. A selector knob sets the correct wire depth. The "go-no go" gauge checks the tool's accuracy. The "positioner" holds the contact in the correct position. The model shown is the DMC AFM, also known as "Little Blue."

D subminiature. The "D" refers to the shape of the connector, which is wider on one side to prevent the plug from being inserted incorrectly. The connector is often used in circuits under about 5 amps, such as power, audio, digital signals and ground.

The D subminiature is made in several sizes, with 15- and 25-pin models common in avionics.

Avoid using D subminiature connectors sold in local stores, the ones intended for a PC. They may work well in the quiet environment of a home, but prove unreliable in aviation service. A good connector will also have a sturdy system for removing strain on the cable.

Molex Connector A plastic block that accepts crimp-type pins, the Molex connector is often found on the rear of mounting trays for avionics equipment. When the radio is slid into the tray, the pins mate with the tray-side connector.



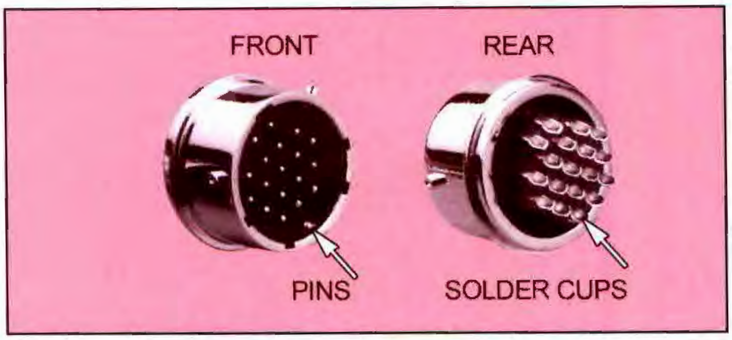
Crimping tool for Molex connectors.

Wire is laid into the Molex pin and the pin crimped in the tool shown above.

Amphenol 57. This series of connectors found in aircraft resembles the D subminiature type. It's used for radio mounting trays, remote-mounted avionics (outside the instrument panel) and for in-line cable-to-cable connections. The pins are available in 14- 24- 36- and 50-pin connector sizes.

To complete the connector, a metal hood is slid over the wire bundle and screwed to the back..

Amphenol 126. Another common number in avionics, this connector is hexagonal. It is often used for autopilots and other applications. Small size, easy assembly and reliability make it a good choice for aircraft. The connector comes in varying numbers of pins; 4, 5, 7, or 9 gold-flashed pins. (A thin layer of gold on a pin resists corrosion.)

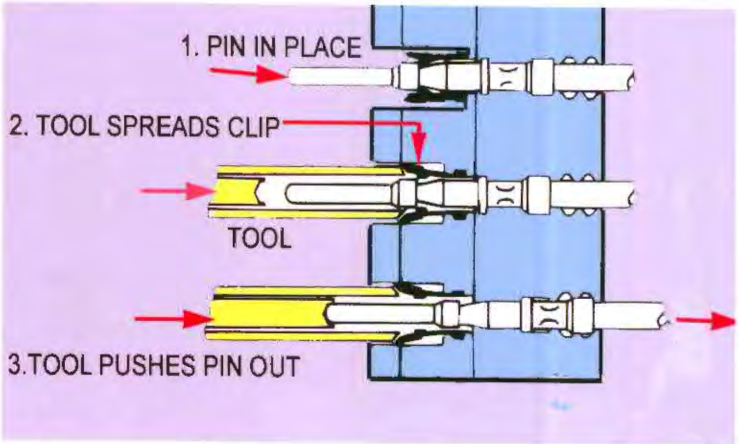


Wires to most connectors are crimped on, but some require soldering. The back of this connector has "solder cups" for holding solder and wire. After the connection is made, shrink-tubing is slid over bare wires to prevent short-circuiting.

Releasing Connector Pins

DMC

A variety of tools is available for installing and removing connector pins, either front or rear release. Although these tools may be offered in plastic, metal is preferred for durabillty.



DMC

To release pins (1) from a connector, the removal tool is inserted over the pin (2). When the tool seats, it spreads a spring which retains the pin. Now when the tool is pressed further, the pin is pushed (3) out. Shown here is a "front release" connector. Other connectors may be "rear release," but the principle is similar

Heat Gun for Shrink Tubing

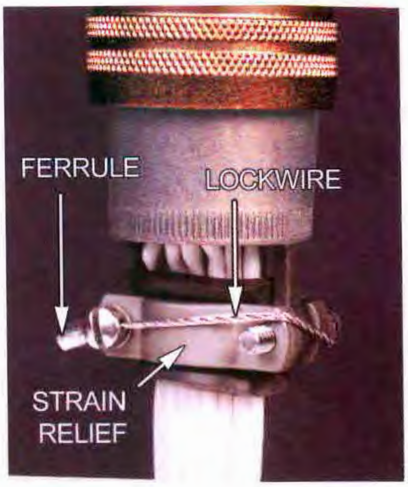
A heat gun (also called a "hot air" gun) is essential for heat-shrink tubing and solder-sleeving.

Effectiveness is greatly increased by adding nozzles, shown at right. They curve and concentrate hot air on the work, which creates equal and faster heating. Nozzles come in different sizes for work of various diameter. The nozzle at the top, however, should handle most avionics jobs. It has a 1-1/2-inch diameter.

Steinel

A heat gun like this Steinel 1802 has selectable temperature from 120 F to 1100 F (50 C to 650 C). It consumes 1500 watts at 120 VAC.

Safety Wiring Connectors



Strain relief for cable is provided by clamp at back of connector. Screws are secured by safety wire applied by tool. (Illustrations: DMC)

1. Pre-twisted safety wire is inserted into fasteners. A ferrule has been crimped to one end (upper right).

2. The other end of the wire is inserted into the tool nose, which stores ferrules.

3. As the tool is squeezed it crimps a ferrule on the wire and applies correct tension. The wire is trimmed flush with ferrule.

4. Completed job. It takes a fraction of the time required by manual safety wiring and eliminates sharp ends.

Besides safety wiring connectors, as shown above, it is recommended in other areas. If the covers of junction boxes, panels, shields or switch housings cannot be accessed in flight, and they are not fastened by self-locking hardware, they should be safety wired.

Review Questions
Chapter 24 Connectors

24.1 What is a major cause of failure when newly-installed equipment is first powered up?

24.2 What is one of the most common RF (radio frequency) connector types?

24.3 Soldering wires to connectors has mostly been replaced by ___________.

24.4 Pins are released from a connector with a ___________ tool.

24.5 Shrink-tubing is installed with a _______ _______.

24.6 What is the purpose of a safety wire (also known as a "lock wire")?

Chapter 25

Wiring the Airplane

During the 1990's, following major accidents, investigators raised questions about wiring in aging aircraft. The result was a government-industry task force that examined 120 jet transports flying in regular service. The results were surprising. Thousands of cracks were found in wiring insulation in just *one* airplane. Metal shavings were seen in wire bundles, wires were tied to fuel lines or attached to hot air ducts. They found contamination by fluids and chemicals and improper use of clamps.

These faults are time bombs---ticking away until they might explode into a disaster. In one B-747 accident, investigators determined that sparks from a high-voltage cable arc'ed over to a low-voltage wire and travelled to a fuel tank. So widespread were such problems that any aircraft over 10 years old was said to have an aging wire problem.

A E Petsche

Wiring made for aircraft is tough and heat-resistant. To avoid long-term problems, avoid anything less than aviation-grade.

In the SWAMP

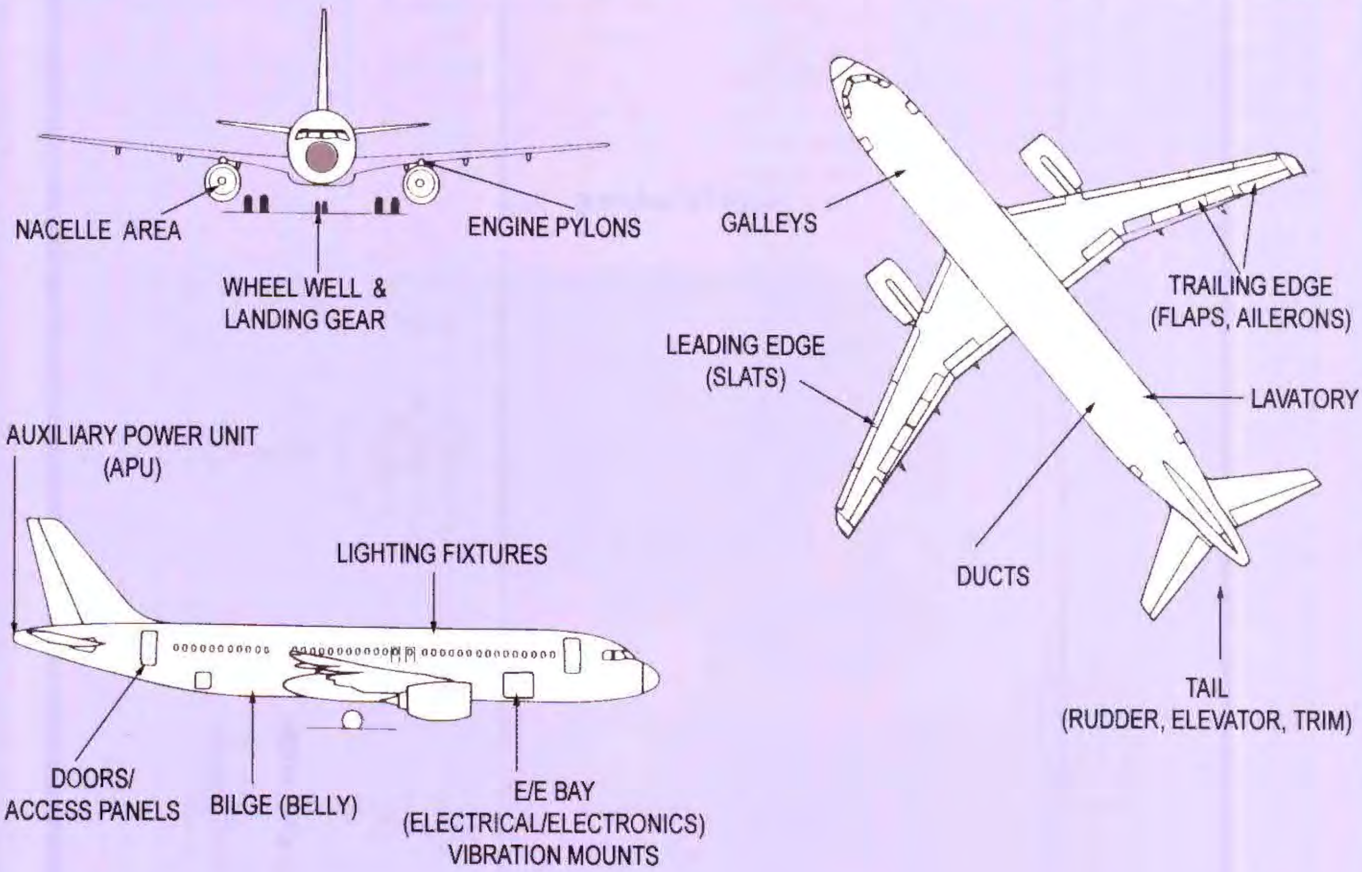
Routing wires is so important that certain places on an aircraft are known as SWAMP areas, meaning "Severe Weather and Moisture Prone". These include engine compartments, leading and trailing edges of the wing, landing gear and wheel wells.

Researchers frequently observed poor installation techniques. Cables were bent too sharply, wire bundles not properly supported, high and low power cables run in the same bundle and improperly-installed connectors. They discovered that certain wire types were prone to cracking and carbonizing, which spreads the danger to other cables.

In some cases, when mechanics performed maintenance on an airplane, they unknowingly damaged wire by stepping on it. They also grabbed wire bundles to use as hand-holds---which cracks the insulation.

The investigation learned a lot about aircraft wiring, improved insulation and a greater awareness of installation techniques. Many of their recommendations appear throughout this chapter.

High Risk Areas for Wiring



Aircraft wiring must operate in a hostile environment. Passengers on the ground in Phoenix, Arizona, in summer are comfortable in the cabin, but a few feet away, wiring may be heated to over 100 degrees F. Minutes after takeoff, temperatures drop below 0 degrees F. Vibration is continuous and humidity swings over a wide range, often causing moisture to condense in hidden places. Certain areas, pictured above, have proven particularly damaging to wiring which has not been carefully installed and inspected.

***Wings: leading and trailing* edges.**
The problem is flaps, slats and ailerons. Because they extend during takeoff and landing, they expose the inside of the wing to the environment.

Engines
Heat, vibration and chemicals are hazards in areas which house the engine; such as nacelles and pylons. This also applies to the engine in the tail---the Auxiliary Power Unit (APU).

Landing Gear
Rocks, mud, water and ice are thrown against wheel well and landing gear, where numerous harnesses run.

Galleys and Lavatories
The drains below these areas must be kept clear and flowing. Otherwise, wiring is damaged by water, coffee, food, soft drinks and lavatory fluid.

Doors and Windows
Look for signs of water damage on wiring in these areas: below a cockpit side window that slides open, under doors used for passengers, cargo and service entry.

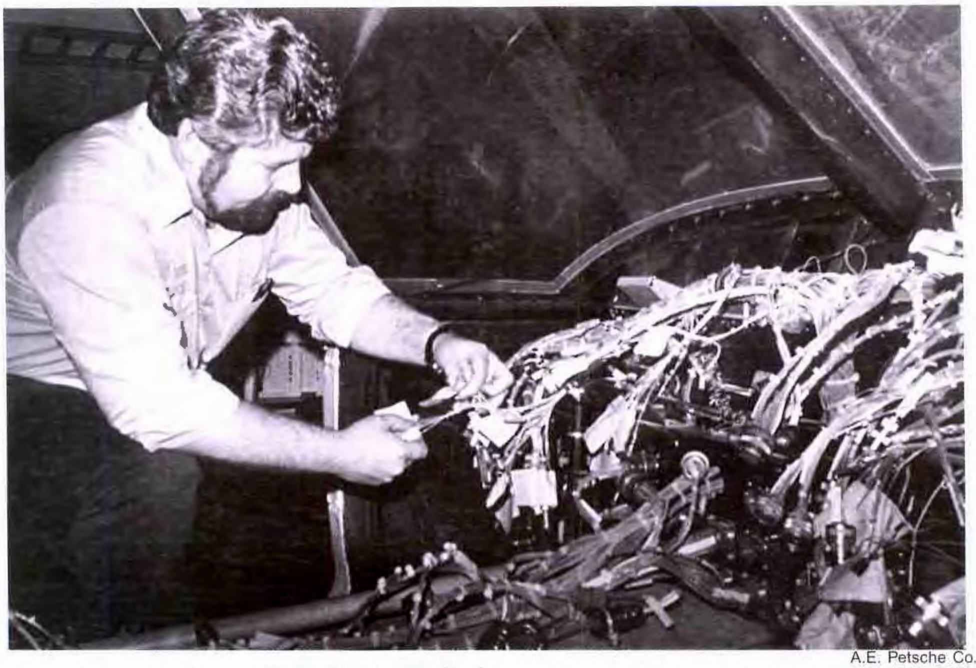
Ducts
If hot air escapes from a broken duct, it may not burn the wire but weakens the insulation until cracking causes problems.

Bilges
Liquids---water, fuel, oil, hydraulic fluids--- flow to the lowest point, which is the bilge, or low point in the belly.

SWAMP
Many of these areas are known in the aviation trade as SWAMP, "Severe Wind and Moisture Problems."

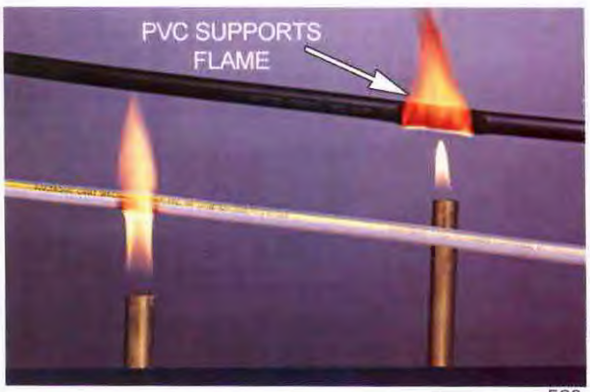
Failures in wiring may be sudden and catastrophic. When a radio is turned on for the first time, a wiring error may cause a short-circuit. Trouble appears in an instant and, hopefully, a circuit breaker prevents further damage. But most wiring problems don't happen that way. More often, a slowly building condition reaches a critical stage years later and causes a failure. Unfortunately, they create the most difficult symptom to deal with---the intermittent connection. A pilot squawks the problem to the maintenance department, but when the technician checks the airplane, he finds nothing wrong.

It's important to note that nearly all problems that appear in new wiring can be avoided without spending much extra installation time or material.

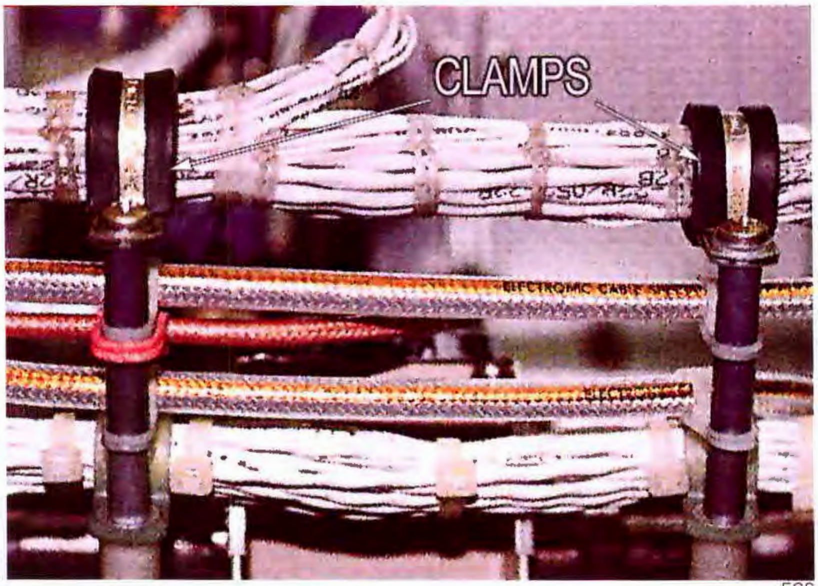


A.E. Petsche Co.

Poor wiring is often called a "rat's nest" but that's not the case in this example. The technician is carefully labelling every wire. Note that all wiring is formed into neat harnesses.



ECS



ECS

PVC wire was banned by the military, then in commercial aircraft. Besides supporting flame, PVC spreads toxic fumes. Aviation wire is now related to Teflon (left). In photo at right, wire bundles are carefully supported by clamps and cable ties.

Selecting Wire

Although wire is a fraction of the cost of an avionics installation, it is critical to safety of flight. Skimping on wire quality makes little sense considering the amount of damage it can cause.

When asked to quote on an extensive avionics upgrade, some shops will not re-use existing wiring in the airplane. They've learned from experience that old wiring harbors many potential defects and makes it difficult for a shop to guarantee its work. When this is explained to the airplane owner, he often accepts the decision to re-wire. In fact, it may cost more, in the long run, to maintain old wiring, especially if older wire types were installed.

Wire quality has made much progress. Copper is the conductor of choice because it combines good conductivity at a reasonable price. In aviation, conductors are usually stranded because multiple wires absorb vibration better than solid wire. Copper is typically plated (or "tinned") with silver or tin for good solderability and resistance to corrosion.

Aircraft makers have used aluminum wire to save weight (and cost). That effort failed when they discovered that aluminum corrodes at the connecting terminals. Increasing electrical resistance here generates heat and a fire hazard. (For the same reason, aluminum wire was banned in house wiring many years ago.) Today, the technician may find aluminum still used between the starter and battery in some light aircraft, but many have been converted to copper.

A jumbo, like the Boeing 747, has nearly 150 miles of wiring which weighs a ton and a half. With rising fuel prices, wire is a target for reducing weight. Military aircraft are even more sensitive because weight reduces performance and payload.

Over 50 years, wire producers responded by reducing the weight of wire by 25 percent. It's been done with wires of higher temperature rating, which allows copper to be reduced in diameter. There are now better materials for insulation that can be applied in smaller thickness.

High-Grade Aircraft Wire

Wire for aviation often has "Tefzel" insulation (in the Teflon family), with copper conductors plated with tin. A typical rating is operation up to 150-degrees C. Fire-resistant wire may have nickel-plated copper to withstand higher temperature---up to 260 degrees C and multi-wall insulation. Made to Mil Specs, aviation wire is typically rated to 600 volts. These wires are the choice of major airframe builders for installation in new aircraft and used throughout General Aviation for upgrading avionics.

Below is an excerpt from a *Wiremasters* spec sheet describing characteristics of a 2-conductor shielded cable.

Wiremasters

Tin Plated Copper Tefzel Shielded Cable

Conductors: 2
Gauge: AWG 22
Shielding: Round Tin coated Copper 85% Min Coverage
Jacket: Tefzel
Conductor Color Code: White, White/Blue
Voltage Rating: 600 Volts
Temperature Rating: -55 to +150 Degrees C
Weight: 12.40 lbs/Mft
Conductor OD: 0.030" Nominal.
Outside Diameter Over Finished Cable: 0.124 inch
Insulation: ETFE (Ethylene Terafluoroethylene)
Mil Spec: MIL-DTL-27500-22TG2T14

Recommended Wire

Before looking at wire types, consider what *not* to use.

Avoid PVC. This is the common plastic-covered hookup wire sold in local radio and auto stores. FAA tests show that PVC insulation burns nearly twice as fast as the legal limit of 3 inches per second. It burns with large amounts of smoke and produces hydrochloric acid when exposed to moisture.

Mechanics have reported that simply moving wire bundles with PVC in old aircraft caused wires to break and short.

Avoid Poly-X. Both civil and military users have had problems in cracking and abrasion.

Do not use Kapton wire. It's caused problems in civil and military aircraft.

Tefzel: Aircraft Wire

At the time of this writing, Tefzel is a recommended wire for aircraft installation It is extremely resistant to abrasion and does not support flame or fire. It won't generate large amounts of smoke if overheated. It resists the attack of moisture, chemicals and cleaning compounds. Tefzel is in the Teflon family and is also known as ETFE (Ethylene Terafluoroethylene). It's available from aviation distributors and wire manufacturers.

Wire Size

Most wire sizes are shown in the chart at the right, and run from AWG OO (over one-third inch thick) to AWG 38, which is like a strand of hair. For avionics work, sizes mainly fall within the range of AWG 14 to 22. For example, No. 22 gauge wire is often used in audio, mike keying, headphone and instrument lighting. Higher current devices such as landing and navigation lights and pitot heat (in light aircraft) may require No. 14 gauge wire. An alternator, which generates large currents (60 amps or more) may require 8 gauge, while a starter motor, which draws the most current, may call for a No. 2 conductor.

The most important rule is to follow the equipment manufacturer's guidance. The maintenance manual states the correct wire size and type (shielded, twisted, etc.) for each connection. That information is on the wiring diagram, but often in tiny letters that may be hard to read, as in this example:

ALL WIRES ARE 24 AWG MINIMUM UNLESS OTHERWISE NOTED

Note the word "minimum," which implies you can use a larger size. That may not harm electrical performance, but large wire presents other problems. First, a bigger conductor may not fit into the connector or terminal. It also takes up more room in a clamp. In large aircraft, it adds weight and size and most airframe builders are actively against this.

Wire Sizes

American Wire Gauge (AWG)

As the AWG number goes *up*, the wire becomes narrower and resistance (in Ohms) increases.

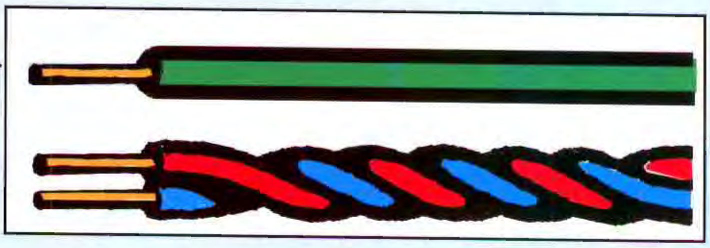
AWG Wire Size	Ohms per 1000 ft	Diameter, Inches
00	.078	.3648
0	.0983	.3249
1	.1239	.2893
2	.1563	.2576
3	.1970	.2294
4	.2485	.2043
5	.3133	.1819
6	.3951	.1620
7	.4982	.1443
8	.6281	.1285
9	.7925	.1144
10	.9987	.1019
11	1.261	.0907
12	1.588	.0808
13	2.001	.0720
14	2.524	.0641
15	3.181	.0571
16	4.018	.0508
17	5.054	.0453
18	6.386	.0403
19	8.046	.0359
20	10.13	.0320
21	12.77	.0285
22	16.20	.0253
23	20.30	.0226
24	25.67	.0201
25	32.37	.0179
26	41.02	.0159
27	51.44	.0142
28	65.31	.0126
29	81.21	.0113
30	103.7	.0100
31	130.9	.0089
32	162.0	.0080
33	205.7	.0071
34	261.3	.0063
35	330.7	.0056
36	414.8	.0050
37	512.1	.0045
38	648.2	.0040

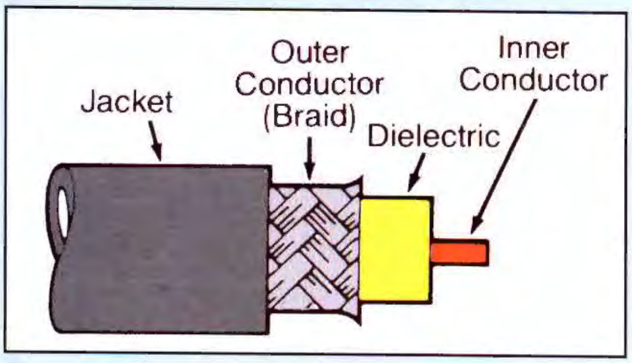
Wire diameter is measured without insulation.

Wire and Cable Types

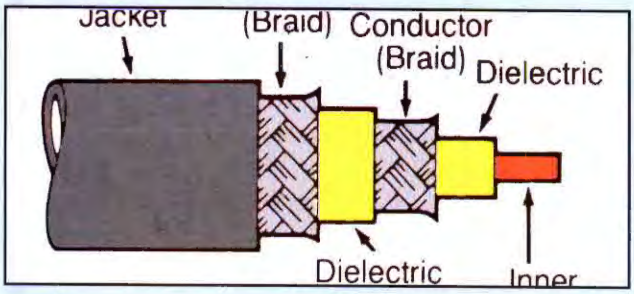
Single conductor has center wire and insulating jacket.

Twisted pair is less susceptible to picking up, or radiating, interference. Twisted pair cables are often shielded for further protection.

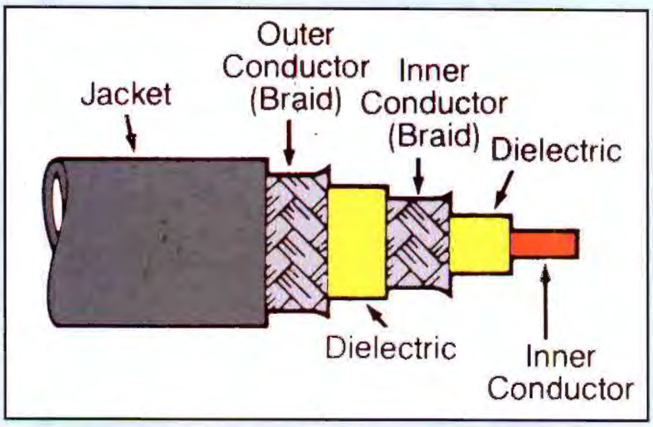




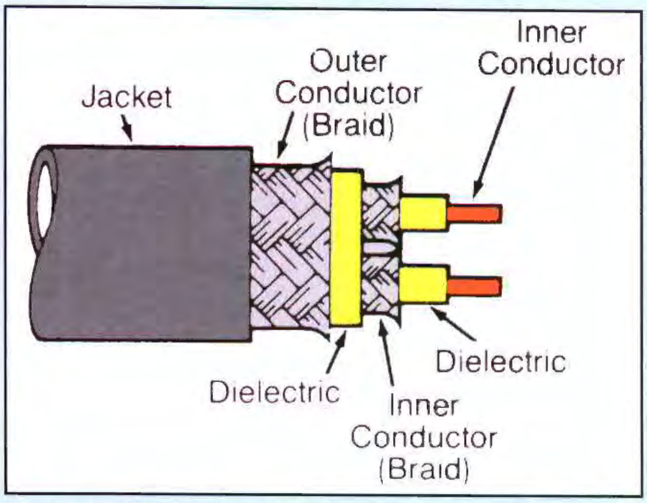
The most common coaxial cable has one center conductor surrounded by a dielectric (insulation) and an outer jacket. Until not long ago, the jacket was made of PVC, a material now banned for new installations but still found in airplanes. The old cable, "RG-58" is replaced by higher-temperature cables (such as RG-400) which are also more resistant to abrasion. Coaxial cables are mostly used to connect transmitters and receivers to antennas. The most common rating in aircraft is "50 ohms impedance."



"Twinax" cable has a pair of insulated conductors inside a common shield. The inner conductors may or may not be twisted, depending on the application. Twinax is used where the cable must have excellent immunity to electrical noise---high-speed data transmission, for example, a type of signal that's growing rapidly in aircraft.



Triaxial cable, with two outer conductors separated by insulation. The outer conductor (braid) serves as a signal ground, while the other is an earth ground. This arrangement provides very high immunity to electrical noise.



Dual coaxial cable contains two separate coaxial cables covered by a common outer jacket.

Coax Illustrations: Anixter

In large aircraft, wire sizes are part of the airplane's Type Certificate and must be observed for legal reasons. When a manufacturer builds a new piece of avionics for an old aircraft, he may obtain an STC (supplemental type certificate). In that document, wire sizes are described in detail.

In the absence of manufacturer information, the FAA provides guidance on choosing an exact wire size. It is described in detail in Advisory Circular 43.13-1B-2B. If you need to look further into the design of an aircraft wiring system, this is the primary reference.

Consider these factors for installing cables, harnesses, bundles and other wiring methods:

Stranded vs Solid

Solid wire is usually to be avoided in aircraft. As mentioned earlier, stranded wire is flexible and less affected by vibration. If stranded wire is called for, don't attach it directly under a screwhead, or the strands might break. First connect a ring terminal to the end of the stranded wire.

Single and Bundled wires.

If wires are strapped together in a harness (or bundle) they are unable to dissipate heat as readily as in free air. This affects the amount of current allowed to flow in the wire; a bundled wire is rated to carry less current. It's most important when wires carry high currents of several amperes or more.

Length

The length of a wiring run affects current-carrying capacity. If the run is long, wire size might have to be larger (smaller AWG number) to prevent excessive heating and voltage drops. (See table.)

A wire stripper, like this manual type, should have notches to match different wire sizes. A high-quality stripper remains sharp and has a return spring. At the right is a semi-automatic stripper. It grips the wire as blades cut and remove the insulation.

Wire Stripping

Removing insulation from wire takes skill---as shown by the fact that FAA permits a wire to be installed with damaged strands. (The illustration gives the details.) That damage usually happens during wire stripping, when the wire is nicked (or scratched).

Strippers. A cheap wire stripper causes trouble and wastes time. It may have adjustable jaws but no method for setting to the wire size. Low-cost strippers do not retain sharp cutting edges, which increases the risk of damage.

A well-designed stripper has V-notches for different wire sizes. This prevents cutting past the insulation and into the wire.

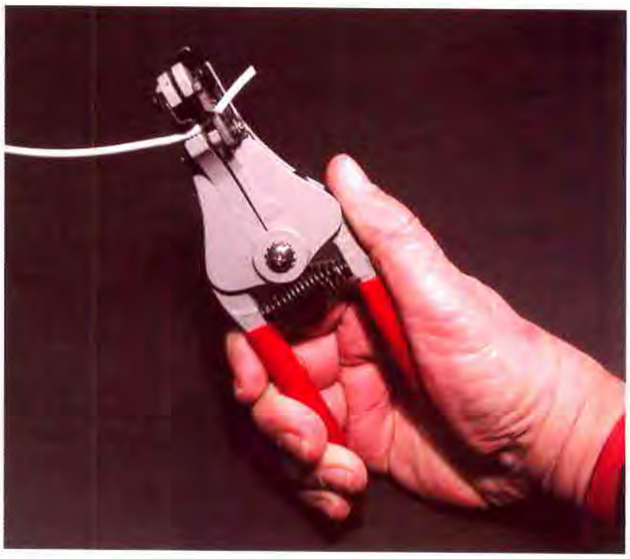
The semi-automatic wire stripper is effective in both holding the wire, then stripping it at a squeeze of the handle. Be sure the wire is inserted into the correct "V" notch.

Some experienced technicians don't like any kind of automatic stripper and prefer the simplest type. Over the years they've developed a sensitive feel by hand and know just how deeply to cut into the insulation, before pulling it off the wire. But today's wire has tougher insulation and is more difficult to cut. A well-made precision stripper takes away the guesswork.

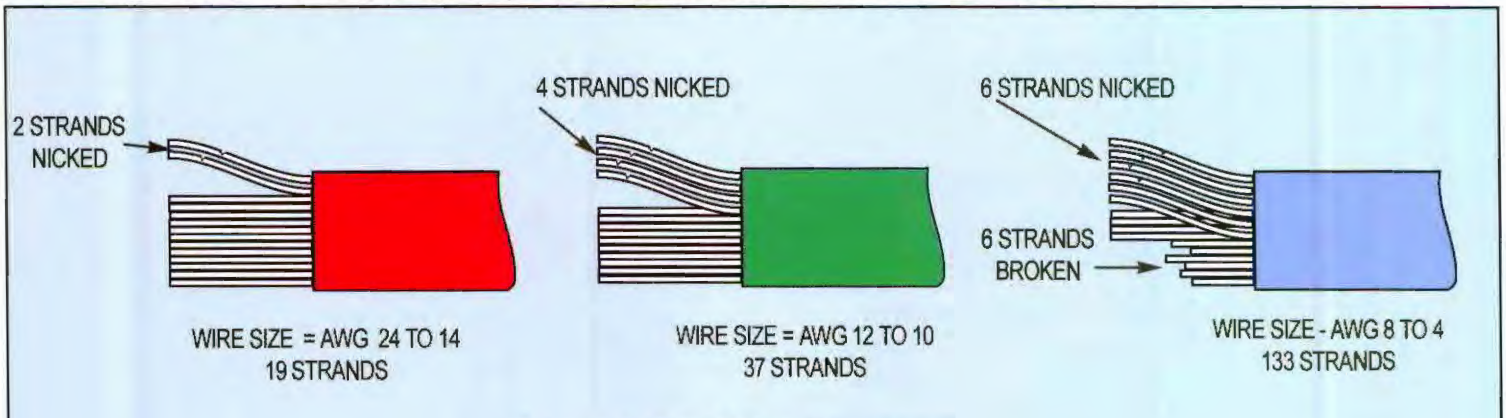
Coaxial cable is delicate because just below the insulating jacket is a braid of fine wire (the shield) that is easily damaged. The shield must be in tact because an incomplete shield changes electrical properties of the cable.

Cutting coaxial cable requires a special technique. You can buy an automatic stripper or use a razor blade to carefully score and remove the jacket.

The two hazards in any wire stripping are strands that are cut completely cut through or nicked (cut part way through). Nicked wires usually break after bending several times or are subject to vibration. When a connection is made, loose strands of wire may touch and short out nearby circuits.



What To Do About Nicked or Broken Wires



Acceptable Wire Damage

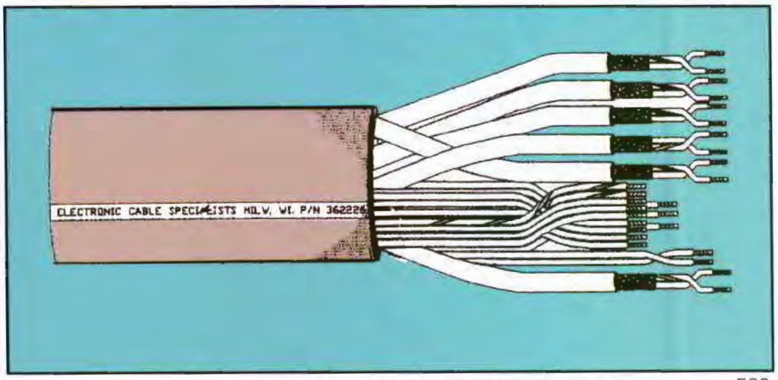
If you accidently nick or break a strand of wire, you may be able to install it anyway by following FAA guidelines shown above. Determine the number of strands in the wire (a figure usually available from the supplier, or simply count them). As shown in the first example, at the left, there can be two nicked strands in wires from AWG 24 to 14, so long as all other strands are in tact. Broken wires are allowed in larger wires at the right, which can contain 133 strands.

Precut Cables

For some avionics systems, prewired cables may be supplied by the manufacturer or obtained from a company which specializes in fabricating cable harnesses. Some come with connectors, others require the technician to install the connectors.

Factory precut or prewired cables should never be shortened or lengthened unless the manufacturer indicates otherwise. Some cables are supplied in several lengths--10 feet, 20 feet, etc. If the cable is too long, the excess is coiled up and secured. (Avoid coiling too tightly, as shown in the illustration.)

Cable sets are often made for installation on a fleet of identical aircraft, In this case, cables are already cut to proper length.



Precut cables for advanced avionics systems are often available from suppliers. ECS

Some cables are extremely sensitive to length. Coaxial cables that go to antennas for TCAS and radar altimeters, for example, also act as timing devices. If they're altered, the pilot will see targets in the wrong place or incorrect altitude above ground.

Splicing Wires

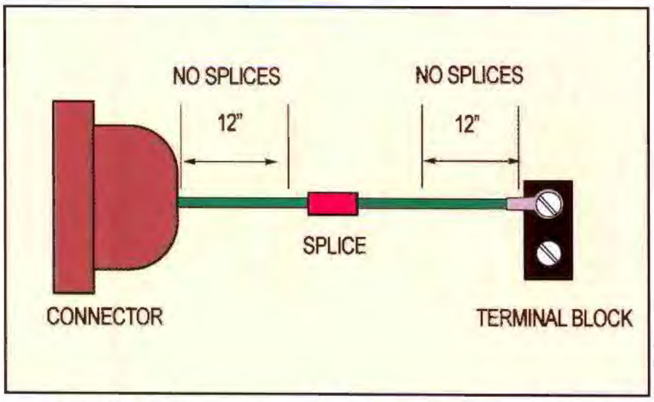
A large part of a technician's job is joining wires to connectors and other terminal devices. Once the connector is wired, there are requirements about splicing the cable to other wires.

Coaxial cable. The efficiency of this cable depends on precise spacing between its outer shield and inner conductor. It is difficult to splice without affecting those dimensions.

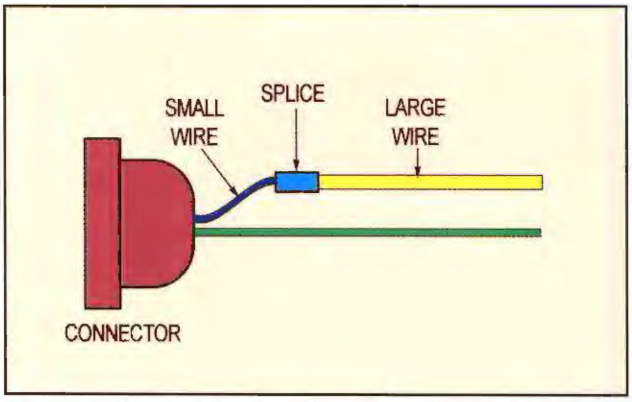
Power wires. Heavy copper cables from the battery, alternator or starter cannot tolerate even a small resistance from an imperfect splice. It lowers voltage of the whole electrical system or heats up and causes a fire hazard.

Databus (Multiplex) cables. Increasingly, avionics systems communicate with each other with digital signals sent through a twisted, shielded pair. A poor splice changes electrical properties and distorts the shape of the signals.

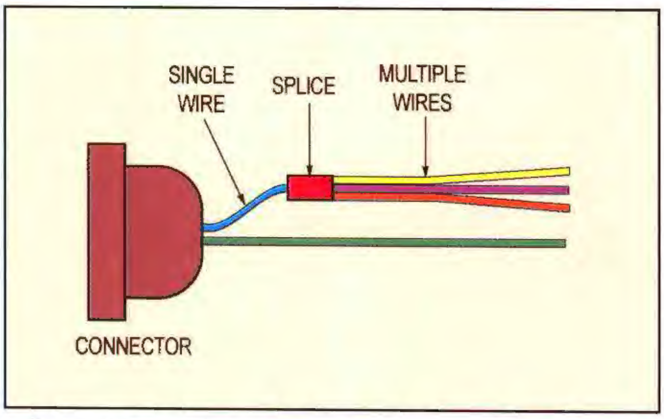
Location of Splices



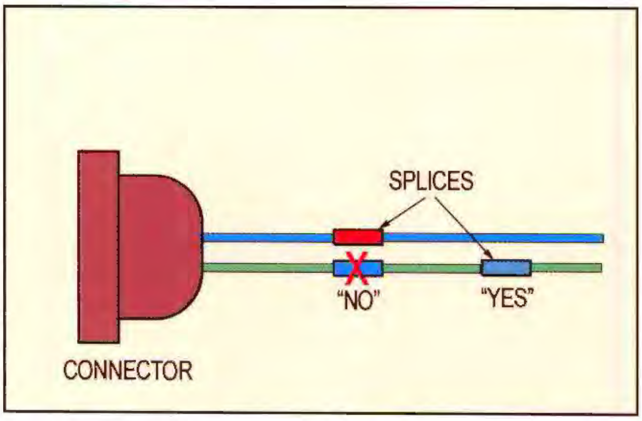
Avoid splicing a wire more than once in a segment, which runs between any two terminal points, such as a connector, terminal block or disconnect point. (There are certain exceptions.) Note that a splice should not be less than 12 inches from the terminal points at either end.



An exception to "one-splice-per-segment" is shown above. If a wire is too large for the connector, splice it to a smaller wire. The small wire from the connector, known as a "pigtail," can be crimped to a connector contact.

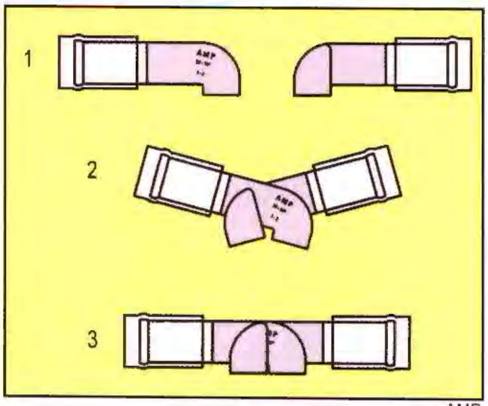


Another exception is when multiple wires need to go to one pin on a connector. They can be spliced to a single wire at the connector.



Each of the wires from this connector has a splice. Do not locate splices adjacent to each other. Stagger them to prevent overlapping, which causes bulges in the wire bundle that might not fit into tight spaces. Bulges also make future maintenance more difficult.

Knife splice is used for quick disconnect.
1. Two ends of the splice are shown apart.
2. The ends are angled together.
3. Push down and the splice is locked.



AMP

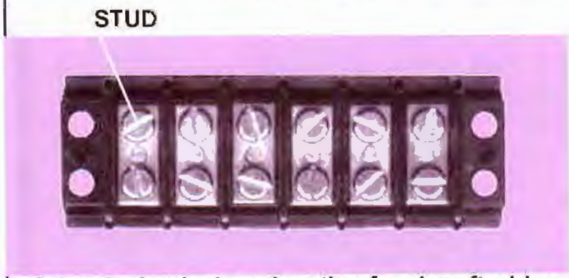
Ring Terminals

AMP

Ring terminals are color-coded according to the range of wire sizes they accept. For example, red takes any wire from AWG 22 to 16. Also choose the stud size the ring must fit over. For example; the first stud size on the list takes a #4 screw. All ring terminals are crimp-on and self-insulated, except the bare one at top right.

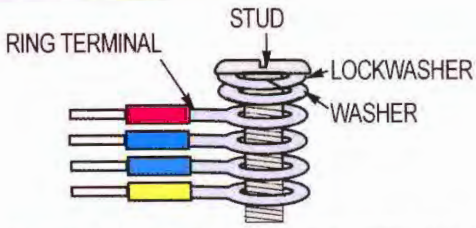
WIRE SIZE	STUD SIZE	COLOR
22-16	#4	Red
22-16	#6	Red
22-16	#8	Red
22-16	#10	Red
22-16	1/4	Red
22-16	5/16	Red
22-16	3/8	Red
16-14	#4	Blue
16-14	#5	Blue
16-14	#8	Blue
16-14	#10	Blue
16-14	1/4	Blue
16-14	5/16	Blue
16-14	3/8	Blue
12-10	#6	Yellow
12-10	#8	Yellow
12-10	#10	Yellow
12-10	1/4	Yellow
12-10	5/16	Yellow
12-10	3/8	Yellow
12-10	1/2	Yellow

Terminal Strip (or "Block")

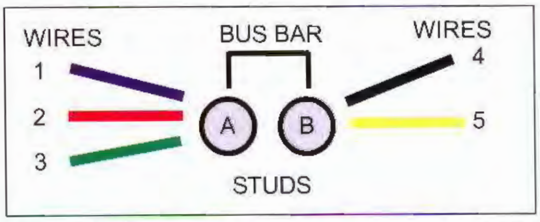


A terminal strip is a junction for aircraft wiring, providing easy access for wiring changes and troubleshooting. This is a 6-terminal strip with 12 studs (each vertical pair is connected together). Be sure to obtain a terminal strip with a raised barrier between studs to prevent short circuits. If the strip is open, use a protective cover made for the purpose. It's a good idea to obtain a strip with extra contacts for future additions, and if a stud is damaged (by stripped threads, for example).

Terminal strips develop corrosion and loose screws over time and need to be checked. Always select a strip that has the size and current rating to fit your terminals.



Do not put more than 4 ring terminals under the head of one stud. If more wires must connect, put *three* ring terminals under a stud, plus a *bus bar* (see below). The bar is a short heavy wire or jumper that joins two adjacent studs. This allows three more wires on the second stud, as shown.



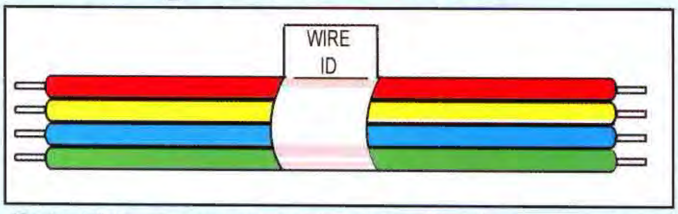
In this example, five wires must connect to one point. Three are connected "A". The bus bar, or jumper, connects "A" to "B". Up to three wires can connect to B without exceeding the limit of four connections per stud.

Marking Wires

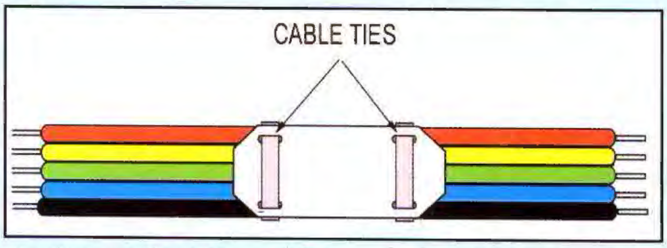
No technician should attempt an installation without marking the beginning and end of cables, harnesses and wires. After each is connected at one end, it's simple to identify the other end and join it to its destination.

Besides marking the *ends* of a wire, it's important to label it all along its run. If this isn't done, when it comes time to troubleshoot the airplane, tracing wires becomes infinitely more difficult. Wires snake through the airframe in inaccessible places and are nearly impossible to trace with your eye. Thus, it is strongly recommended that all new wiring be clearly identified all along its route.

Marking a Wire Bundle

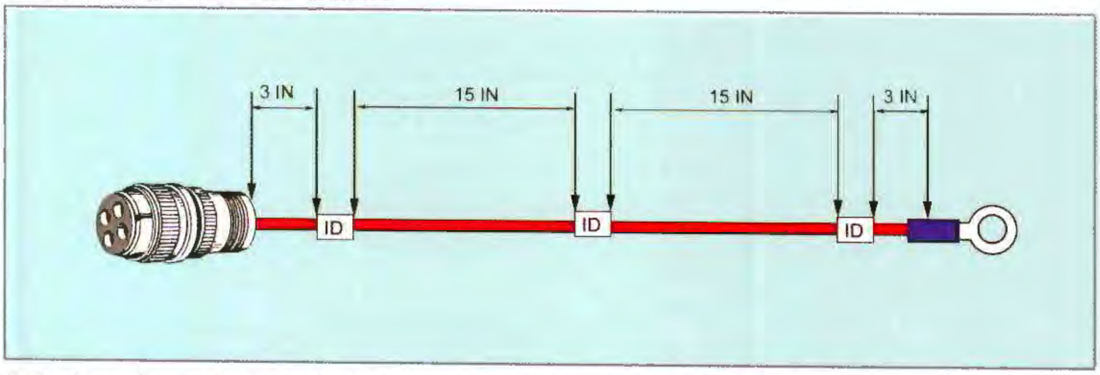


If identifying marks cannot be done directly on the wire, use a pressure-sensitive tape or heat-shrink tubing made for the purpose. Examples of hard-to-mark cables include those with Teflon or fiberglass insulation or wire braid.



Another method for marking a wire bundle is with a tag and cable ties. Where many tags are required, they may be obtained in strips and marked in a printer.

Wire Marker Intervals



Individual wires should be marked. The recommended spacing is an identification ("ID") marker within three inches of where the wire originates (in this example, a connector, and within three inches of where it ends at the ring terminal at the right). Along the wiring run a marker should be installed at a maximum of every six feet. Wires less than three inches long require no ID. Wires between three and seven inches should be marked at about the center.

Marking Methods

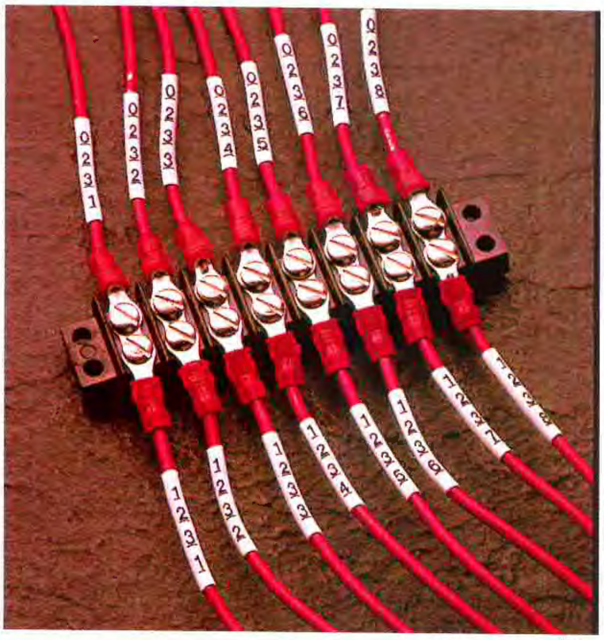
In marking a wire, the information should identify the wire, the circuit it's part of and the AWG, or gauge, size.

Because some wires are sensitive to the surrounding area, don't use metal bands for the ID. Any marking method must not deform a coaxial or databus cable to prevent electrical losses.

The preferred method of marking is *directly* on the wire insulation or jacket. Many jackets, though, especially those made of Teflon, are difficult to mark without expensive laser equipment. Wire with a bare shield is also difficult to mark, as are multiconductor and thermocouple (heat sensor) wires. Where the surface is difficult, you can use the *indirect* method, where you apply a label to a sleeve, then slip it over the wire. The sleeve might be a tube that you heat-shrink onto the wire.

Stamped Marking. In this method, wire insulation is stamped (indented) with a tool and hot ink applied in the depressions. This works well but the technician must follow the manufacturer's instructions and adjust the machine carefully to avoid harming the wire. To avoid damage, the indentation in the wire must be no deeper than 10 percent of the insulation thickness. Very small gauge wire, therefore, cannot be hot-stamped.

Stamped Sleeving. In this indirect method, a sleeve is imprinted with a laser, inkjet or other printer and slid onto the wire. The sleeve is held by various fasteners.



Kroy

Labels marked on white shrink tubing

Wire Bundles. The marking systems just mentioned are for single wires. When they are grouped into a bundle, the ID may not be visible. Sleeving that can be marked and fastened around the whole bundle are readily available.

Harnessing the Wire Bundle

From each radio or instrument, wire branches run to main trunks, then fan out to their separate destinations. A neat, squared-off harness is easier to install and troubleshoot than running each wire directly from source to destination. Direct wiring which criss-crosses in every direction creates the well-known "rat's nest," and is a sign of poor workmanship. A neatly-bundled, squared-off harness also takes up less room behind the panel and is much easier to service later on. (Check for any restrictions in the manual on changing cable lengths, especially for coaxial type).

When an airplane is wired at the factory, creating the harness is easy because it's done on a wiring jig. This is a large board with pegs that guide the wires along neat paths. The engineering department figures out the pathways for one airplane and the pattern is used for all production aircraft.

But many installations are not done to fleets, but custom-built---each one is different. One approach to designing a harness is to make a rough drawing of the panel to determine where each radio or instrument is located, then pencil in the most efficient, obstruction-free route for the harnesses.

EMC/EMI. All wires may not run in the same bundle because they could interfere with each other. It's the problem of EMC, or electromagnetic compatibility. (Sometimes it's known as EMI, for electromagnetic interference.) Wires carrying signals of widely varying power levels transfer energy among themselves. It was once simply known as "crosstalk," but as the number of wires aboard aircraft multiplied, EMC became a major subject of new regulations.

The EMC problem grew worse as avionics became more digital. These signals are very low in level and susceptible to interference.

Many cables (and connectors) are now designed to prevent EMI. Some are protected by braided shields, others are twisted and some have both forms of protection. But shielding may not completely contain the signal, and interference can occur when a transmitter cable (which usually carries high power) is bundled with a low-level cable carrying receiver signals.

Another source of interference is from cables carrying power from an alternating or pulse-type source. In large aircraft, this includes the inverter (part of the power generating system). Strobe lights are frequent interference generators because they operate with short, repeating bursts of power. Pulse-type current is troublesome because it also produces harmonics, signals of much higher frequency that interfere with receivers and lightning detection systems

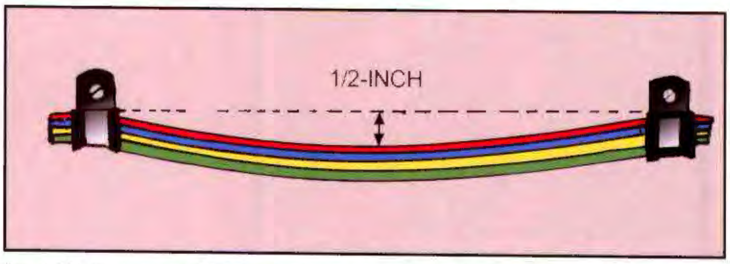
DME's and transponders also send pulses of high power through antenna cables and raise the possibility of interference.

Avoiding Electromagnetic Interference

To reduce chances of interference, keep power and transmitter cables outside the bundles that carry low-level radio, audio, digital and control signals. Several inches of spacing may be sufficient. If those cables run at right angles to the wiring harness, much less energy is transferred.

Dealing with noise is most effective when done at the source. Wires causing interference can be treated by shielding, bonding, grounding and filtering, as described in a later chapter.

The Adel clamp is often selected for supporting wire harnesses in aircraft. It has a cushioned liner to reduce chafing on wire insulation. The clamp is made in several sizes to accommodate wire bundles of varying thickness.



Install clamps at distances no more than 24 inches apart. When you grab the wire bundle and give it a *slight* pull, it should not move axially (to the left or right in this illustration). The bundle may droop up to 1/2-inch under normal conditions. That slack may be exceeded if you are sure the bundle cannot touch a nearby surface and suffer damage from abrasion (rubbing).

Tie Wraps (Cable Ties)

Call them "cable ties," "tie wraps" or "plastic ties"--they're all the same---but these little helpers reduce installation time and make the finished job look neat and professional. Thread the tie wrap, pull, and wires are instantly bundled. Tie wraps can even be attached after the harness is installed.

Installing Tie Wraps. There are precautions. Many a technician has put his arm behind an instrument panel, only to have it scratched or cut by the sharp end of a tie wrap. It happens when the end of tie wrap wasn't properly trimmed (see illustration).

Another precaution: when installing a tie wrap avoid the temptation to pull it very tight. (It's easy to do with little effort.) This squeezes the wires, changes their diameter or cuts into the insulation, making it more susceptible to vibration. Simply pull the tie wrap until it is snugly around the wires---and retains the wire bundle in place---without crushing.

How many tie wraps are required? Use enough to hold the bundle together, as well as support the harness where it changes direction. Install one where small bundles break out from larger ones. In general, if the bundle is not supported for more than 12 inches (by a clamp, for example) install a tie wrap.

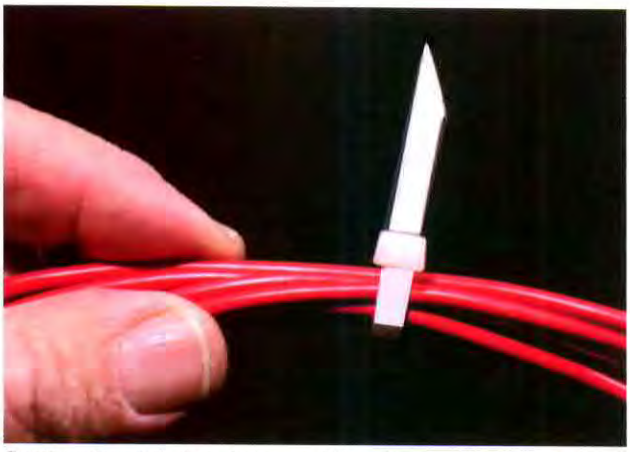
Don't overload the harness with tie wraps before laying it into the airplane. If ties are too close, you may find it difficult to curve the harness around tight corners.

Cable lacing. Before the introduction of tie wraps, wires were laced into bundles by a special cord with a wax coating. Lacing cord is still available, but it has been mostly replaced by tie wraps. Besides requiring more time and labor to install, cable lacing cannot be added after the harness is in place behind the instrument panel. Another problem with lacing happens during maintenance and upgrading. Making changes to a harness is quick and easy with tie wraps, in or out of the airplane. Nevertheless, some technicians cling to lacing cord as a sign of craftsmanship Lacing looks good, but takes considerable effort and time.

Clamping the Harness

Cable ties keep wires together in a bundle. The bundle, however, must also be supported along its run to prevent damage or interference to moving parts of the airplane.

When installing a tie wrap, don't overtighten it. Pull the tab until the tie wrap is snug around the harness.



Cutting the tab too long and leaving a sharp point can injure the next person reaching for the harness under the instrument panel.

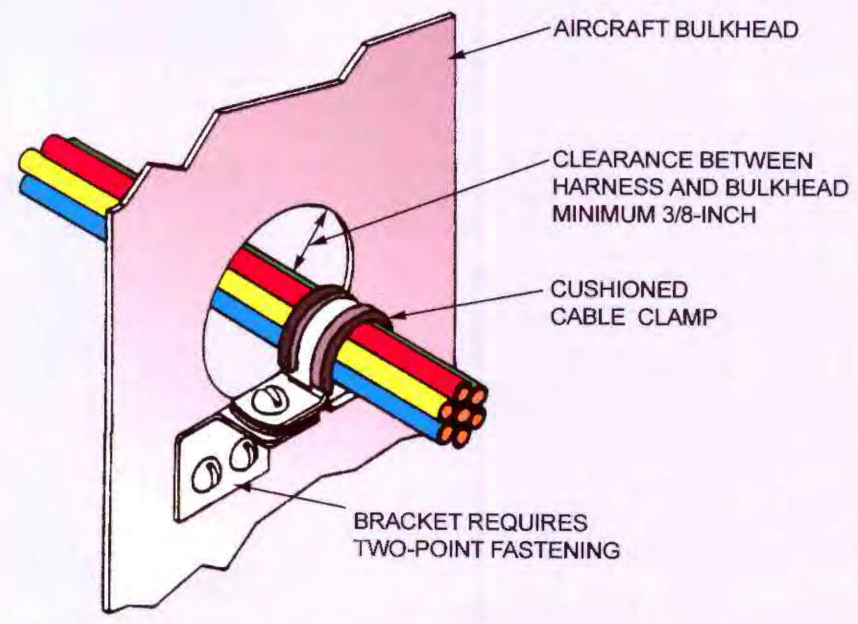
Cut the tab flush with the locking part of the tie wrap.

Where Wiring Problems Begin

Chafing and Abrasion

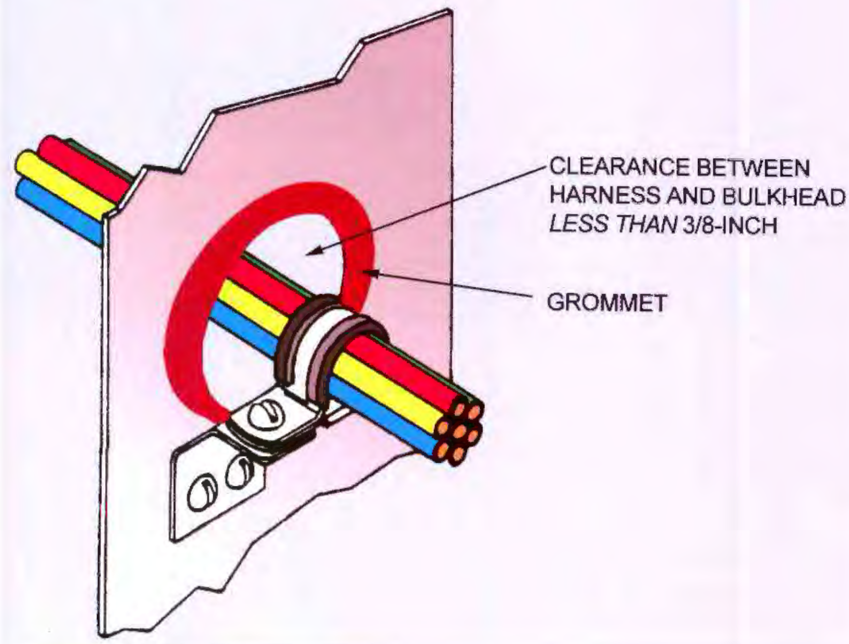
The steady vibration of an aircraft in flight is transferred to wire bundles, rubbing away insulation. This is avoided by supporting wire bundles away from sharp objects and other surfaces. It's done by cable clamps installed along the wiring run, especially where the wire runs through holes in the airplane structure.

1. If wiring harness clears the edges of the bulkhead hole by at least 3/8-inch, only the cable clamp is required at the hole.



When running a harness through a hole, wires must remain at least 3/8-inch away from the edge.

2. If wiring harness does not clear edges of bulkhead hole by 3/8-inch, a grommet is required for further protection.



If there is less than 3/8-inch clearance, add a grommet to the hole. There are many openings in an airframe for running wire harnesses. They're known as "lightening holes" because they lighten the airframe. They are not "lightning" holes.

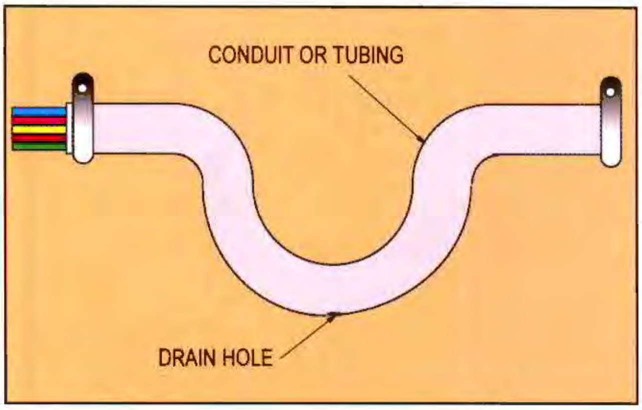
Moisture

Aircraft move through great variations in temperature and humidity, often in the same day. It encourages moisture to form, which then flows to the lowest point. The bottom of the fuselage (the belly of the airplane) is a moisture-prone area. Another troublespot is near air conditioning ducts.

Areas of moisture and high humidity corrode connector pins, terminals, sockets and hardware attached to wiring. Avoid it by supporting harnesses above and away from these areas.

Conduit

In large aircraft, wiring is protected by running inside conduit, but moisture forms inside the tube. After conduit is laid out and fastened, find the lowest point in the system. Make a 1/8-inch diameter hole at the lowest point for liquid to flow out. When wires are installed inside conduit, do not fasten them together with cable ties.



Conduit comes in metal and non-metal versions, rigid and flexible. When selecting a diameter make it about 25% larger than the wire bundle that goes inside. After cutting to length, remove any burrs which might cut the wire. When flexible conduit is cut with a hacksaw, it can have a ragged end. This is avoided by wrapping the end of the conduit with tape before sawing. Conduit also needs to be supported with clamps.

Broken Ducts

A torn or broken duct can direct hot air onto a wire bundle and, over a sufficient period, cause cracks. Even small breaks in insulation might enable a spark to jump across two wires. Look for such breaks in the duct during installation and maintenance.

High Temperature

The way to avoid heat damage is to space the harness away from such high heat zones as heating ducts and engine exhaust. When that's not possible, high-temperature sleeving might reduce the problem. If it's an old airplane, it may contain coaxial cable with a polyethelene jacket, which melts at elevated temperature. Other heat-damaging areas are galleys and lighting fixtures.

Corrosive Chemicals

An airplane is nearly a flying chemical factory and wiring is always under attack. Here are the leading offenders:

Battery acid	Jet fuel
De-icing fluid	Cleaning materials
Hydraulic fluid	Lavatory waste systems
Paint	Soft drinks

Besides injuring wires, dirt, grease and grime make it difficult to read labels on wires and prolong troubleshooting time. If you don't have the manufacturer's recommendation on cleaning wires, use the industry practice; a soft cloth and general-purpose detergent. Check to be sure that cleaning doesn't remove the labels.

Connectors

A vulnerable point is where wiring enters a connector. First, be sure the strain relief is working to prevent pulling on the end of the wire. Look for missing hardware and replace it.

Look at how the wire enters the connector. If moisture forms on the wire can it run down and flow into the connector? To avoid corrosion, form a drip loop in the wire so water cannot run downhill to the connector.

There are times when a connector is removed from a radio and not immediately reconnected. This leaves connector openings exposed to contamination. They need to be covered with a plastic cap. Never force connectors to mate. Be sure the plug is seated in a socket before tightening.

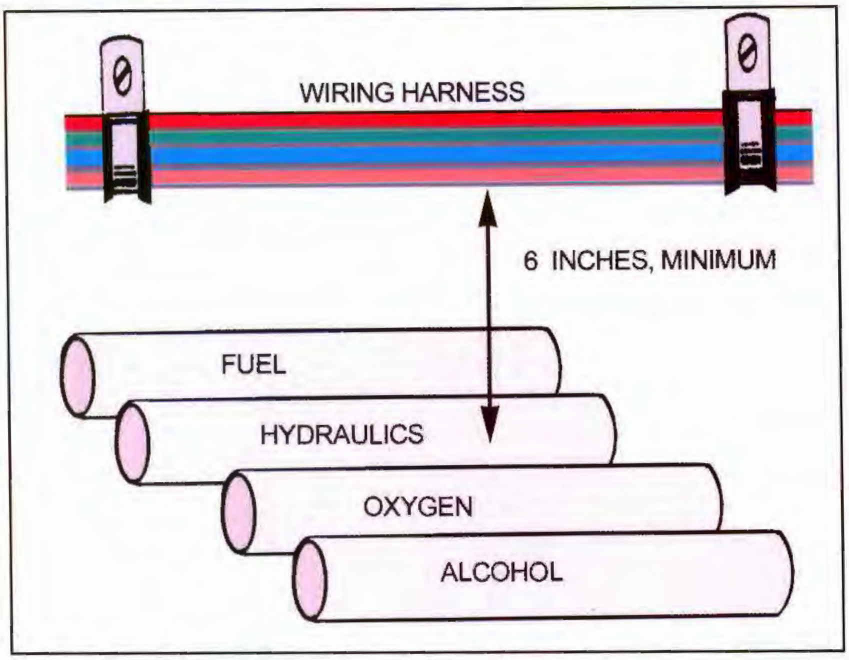
Harnesses, Not Handholds

An airplane is not a friendly environment---not only for wiring, but technicians, as well. In small aircraft, technicians lie upside down under the instrument panel, legs on the seats--- and rudder pedals in their shoulder blades. In large aircraft, the avionics bay is small and cramped. Radios are mounted in tight corners of the fuselage.

There is a strong temptation for the technician to hoist himself out of tight places by grabbing a wire harness like a subway strap. Using harnesses as handholds is discouraged by FAA inspectors, as well as stepping on wires.

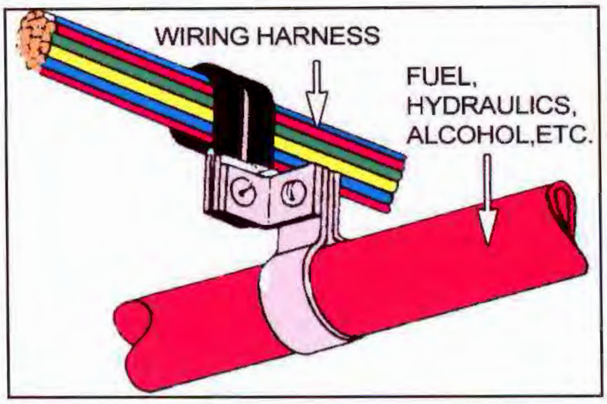
Yet another hazard is leaving metal cuttings, tools and waste material among wire bundles. As an aircraft grows older and wire becomes brittle, these objects cut into insulation.

Clamping Near Fuel and Other Lines

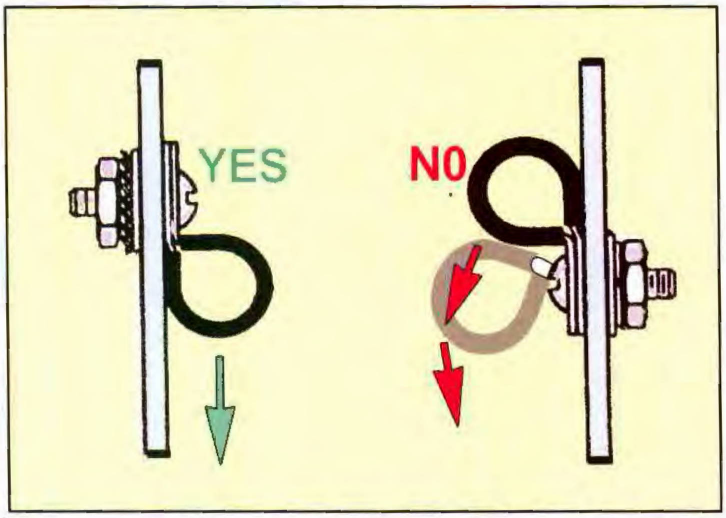


When runnning a harness near plumbing lines that carry flammable liquids or gases, mount the harness *above* them. Try to maintain a clearance of least six inches. If that's not possible, avoid running the harness parallel to those lines and maintain a minimum clearance of two inches

If you can install a clamp near a crossover point, clearance may be as small as one-half inch. When the harness must be connected directly to a plumbing line, use a clamp, as shown here. Don't use that clamp as a regular support for the harness, but use additional clamps. To avoid movement between harness and plumbing lines, install the additional clamps on the same part of the aircraft structure.



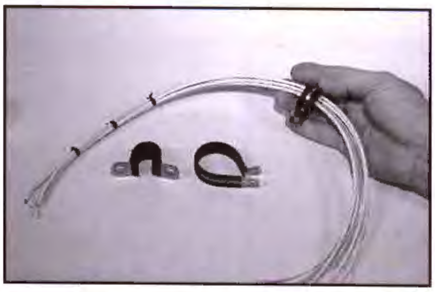
Mounting Clamps

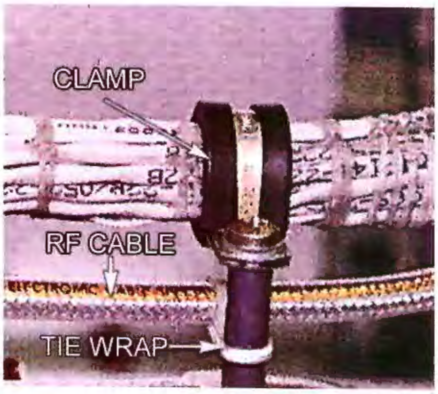


When mounting cable clamps on a vertical surface, locate the nut and bolt *above* the loop that holds the wire (see "Yes"). Placing them below, as shown at "No," may cause wiring to sag if the hardware loosens. This could cause trouble.

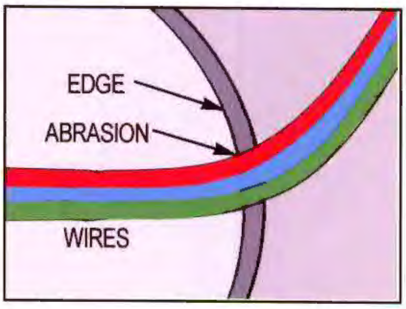
To be sure hardware is secure, use lockwashers (external teeth) or self-locking nuts.

"Adel"clamps come in many sizes and mounting types to support wire harness. They are lined with cushion material to hold the bundle. without chafing or rubbing.





Chafing and Abrasion

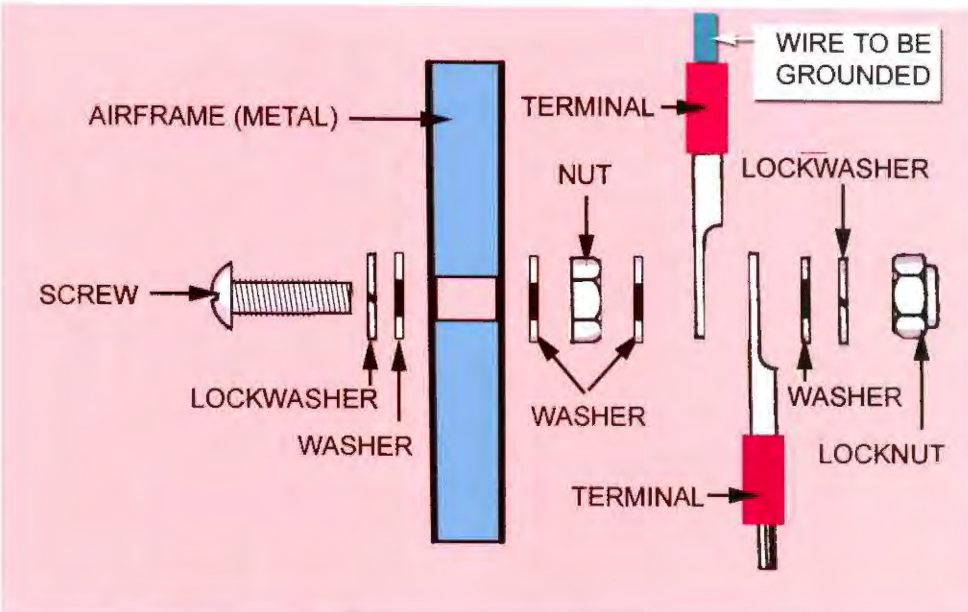


The large wire bundle at the top is supported by a clamp. Wires contained in the bundle carry low-level signals (receiver, data, control, audio, etc.) that don't interfere with each other.

Note that an RF (radio frequency) cable is supported with a tie wrap outside the main bundle. It is good practice to keep transmitter signals (high power) away from low-level bundles.

Large cables that carry power from the electrical generating source (alternerator, battery, inverter, etc.) should also be isolated. Wires from any part of a strobe light system are best kept out of the main wiring harnesses.

Grounding to Airframe

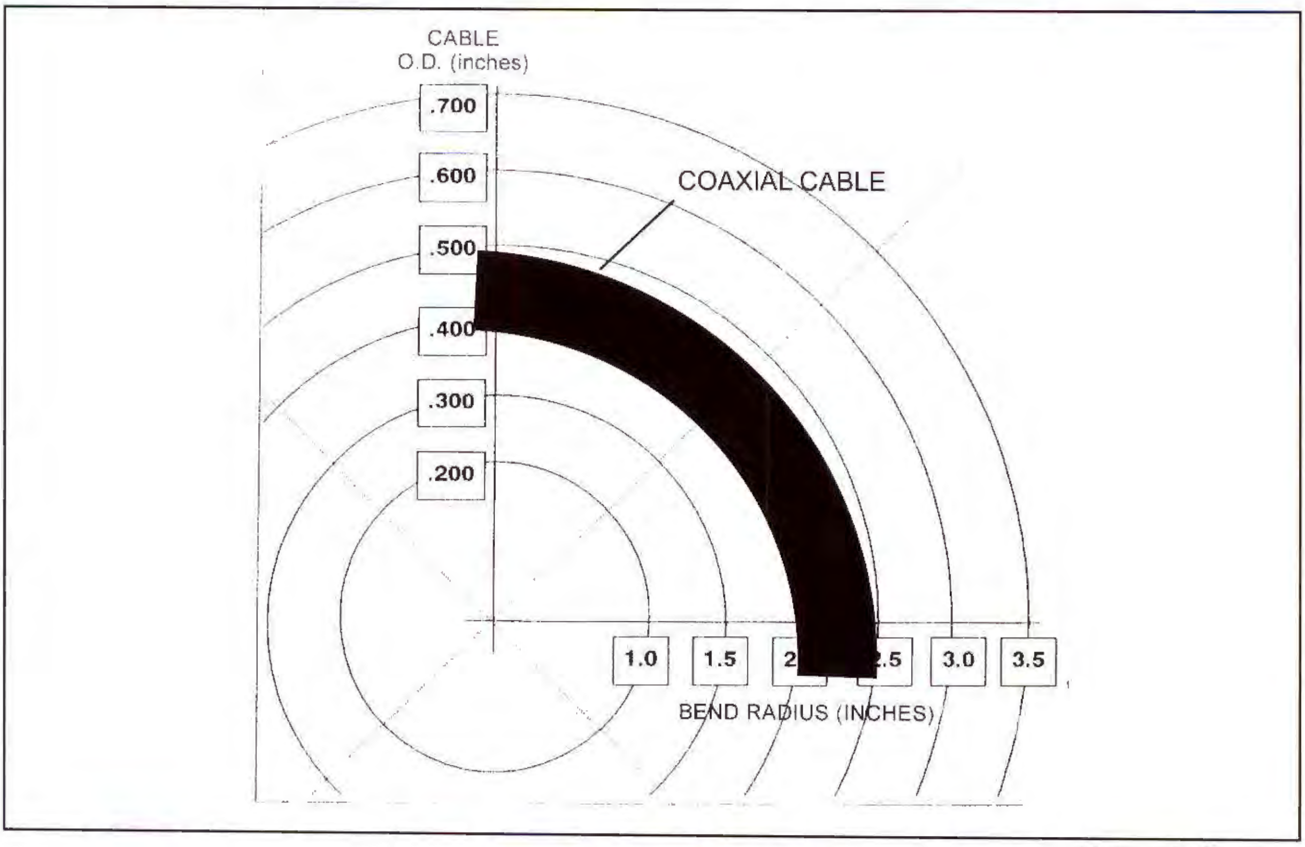


The procedure for attaching wires to the metal structure of the airplane. It serves one of two purposes. One is "grounding," which provides a return connection to the power source for a radio or other electrical device. The whole airframe (if made of metal) is the return connection. The other is "bonding", which connects two surfaces (flaps and wing, for example) with the lowest possible electrical resistance. This reduces the chance of generating interference.

To obtain a good ground, the contact area must be clean. Remove paint, primer, grease and corrosion. If aluminum is protected by a coating of Alodine, remove it.

Two terminals (red) are shown being grounded in the illustration. Do not connect more than four terminals to a single grounding point.

Bending a Coaxial Cable



Bend Radius Template

Pic Wire and Cable

Coaxial cable has two conductors which share the same axis; a center wire surrounded by a shield. Unless they remain perfectly spaced ("concentric") they lose electrical performance and power is reduced.

A common problem occurs when coaxial cable is bent too sharply, which can happen during an installation in the limited space of an airplane. Tight bends shift the position of the center conductor and the result is an electrical (or impedance) "bump" that steals energy.

Another problem occurs when coaxial cable runs near an edge. If the cable pushes against the edge, a kink can form.

To prevent losses, cable designers recommend bending coaxial cable over a radius no less than five times its diameter.

In the illustration is a template which shows the minumum bend for cables of various sizes, with an example using a .4-inch diameter. It is laid over the curve that leads to a 2-inch bend radius.

RG58*	----	0.195 (inches)	1.0
RG142	----	0.195	1.0
RG400	----	0.195	1.0
---	S44191	0.195	1.0
---	S44193	0.195	1.0
SF142B		0.195	1.0
---	S66162	0.230	1.2
---	S33141	0.270	1.5
---	S55122	0.300	1.6
(Example)	T556124	0.385	2.0
RG393	----	0.390	2.0
RG214*	----	0.425	2.5
---	S22089	0.435	2.5
---	R11062	0.640	5.0

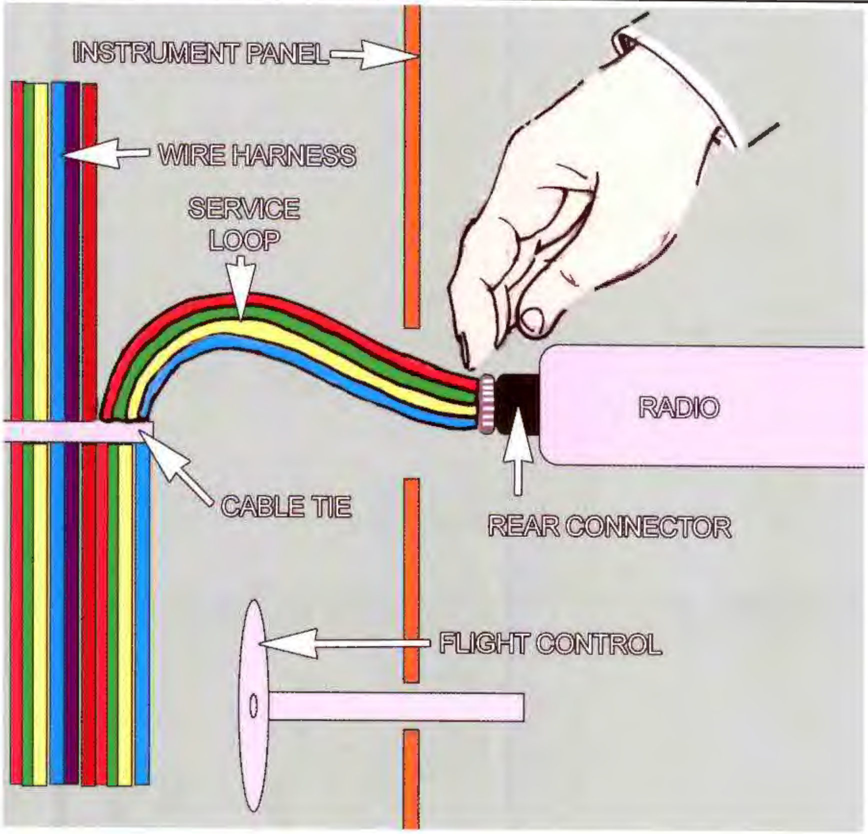
*PVC insulation, not recommended for aircraft

(PIC)

Coaxial cables are shown with their outside diameters (O.D.) and recommended bend radius. By knowing the O.D. the cable may be laid over the template to see the minimum bend radius. The second column, "PIC Cables", shows model numbers from that company's catalog.

The highlighted "Example" is used in the template.

Service Loops



Every radio or instrument should be installed with a "service loop." It is extra slack that permits the radio to slide out of the panel, allowing you to unfasten the connectors. Otherwise, you could spend hours groping behind the panel.

But service loops must be carefully installed to avoid introducing their own problems. Install a cable tie where the service loop breaks out from the harness (there are 90-degree or Y-types for this). Don't bend the wires sharply where they come out of the main harness. Tie the service loop every 4 to 6 inches. If there's any chance of one service loop touching another, cover them with expandable sleeving.

Strain relief is required where the service loop enters the connector at the back of the radio. Frequently, this is provided by the backshell of the connector, but a cushion (Adel) clamp can also mount on the back of the radio.

How long is a service loop? Make it so the radio can be pulled out of the panel by about 3 to 6 inches. This provides clearance to put your hand inside the panel and remove connectors.

Because you are lengthening wires when making a service loop, extra care is needed to prevent the loop from touching moving parts behind the panel (cables, pulleys, gears, etc.). Most movement behind the panel is from the yoke, so move it back and forth and side to side, full travel, to check for rubbing or tangling.

Review Questions: Chapter 25 Wiring the Airplane

25.1 Hazardous areas for wiring on large aircraft are known as "SWAMP." What does it mean?

25.2 What type of wire should never be used for new work on an airplane?

25.3 Why are stranded wires preferred over solid wire for aircraft?

25.4 What type of insulation is found on wire used in many aircraft today?

25.5 As the AWG number for a wire size goes up, the wire diameter _________.

25.6 Which wire has the larger diameter; OO or 36?

25.7 (A) Is it permissible to use wire of greater diameter than required? (B) Are there disadvantages?

25.8 What is the most important rule for selecting wire size and type?

25.9 Unshielded wires are more susceptible to picking up or radiating ___________.

25.10 What should you avoid when stripping insulation from wire?

25.11 How many splices may you insert in a length of wire running between two terminals?

25.12 Why should a wire be labelled every 15 inches along its length?

25.13 What two types of cables should be kept apart to avoid interference?

25.14 Why is it important to keep wire bundles from touching aircraft structures?

25.15 Why should wiring be supported away from the bottom of the fuselage?

25.16 Every wire entering a connector must have some form of __________ to prevent it from breaking out of the connector.

25.17 A wiring harness should run 6 inches or more *above or below* lines that carry fuel, oxygen, alcohol or hydraulic fluid?

25.18 Before grounding a wire to the airframe, what steps will insure a good ground?

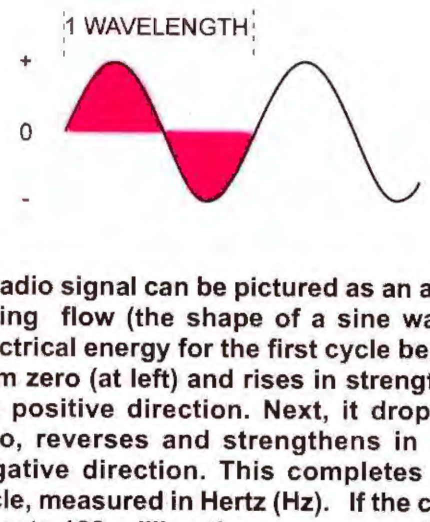
25.19 What is the purpose of a service loop?

Chapter 26

Aviation Bands and Frequencies

Many problems affecting avionics occur in antenna systems that communicate between the airplane, ground stations, satellites and other aircraft. Antennas operate in the most hostile environment; 500-knot winds, wide temperature swings, ice, hail and other foul weather. Inside the aircraft, antennas connect to cables that run through extremes of temperature, humidity and corrosive chemicals. They are sensitive to location, are easily contaminated and require special test equipment to check their operation.

A single-engine aircraft may have ten antennas; airliners have about 20. It was once believed that antennas would drop in number as designers developed new systems that didn't need radio signals, namely the laser gyro. In spite of advances in gyroscopic and laser instruments, the success of satellite navigation and communications increased the number antennas to meet the demand for new passenger, airline and air traffic services.



A radio signal can be pictured as an alternating flow (the shape of a sine wave). Electrical energy for the first cycle begins from zero (at left) and rises in strength in the positive direction. Next, it drops to zero, reverses and strengthens in the negative direction. This completes one cycle, measured in Hertz (Hz). If the cycle repeats 122 million times per second, the frequency is 122 MHz (megahertz), which falls in the aviation com band.

Distance from one cycle to the next is also the wavelength of the signal. There is a direct relation between frequency and wavelength. By doubling the frequency the wavelength is reduced by one half.

Radio Frequencies (RF)

Antennas operate in the world of RF. Radio frequencies form when electrical currents are driven back and forth at about 10,000 times per second and higher. The source is a transmitter, which applies the energy to an antenna. Each time current rushes into or out of the antenna, a field of energy, an *electromagnetic wave*, travels outward.

All radio waves move the same speed; 186,000 miles per second, and consist of electromagnetic en-

Radio Frequency Bands			
Band		**Frequency**	**Aviation Services**
Very Low Frequency	**VLF**	3-30 kHz	1. Omega (now terminated). 2. VLF (Active in submarine operations, no longer used in aviation).
Low Frequency	**LF**	30-300 kHz	1. Non-Directional Beacons (NDB) used by airborne ADF 2. Loran 3. Stormscope, lightning detection,
Medium Frequency	**MF**	300-3000 kHz	1. Non-Directional Beacons (NDB) 2. Standard AM broadcast band (which can be tuned by aircraft ADF).
High Frequency	**HF**	3 -30 MHz	Long-range voice communications for oceanic and flight in remote areas. Some data communications.
Very High Frequency	**VHF**	30-300 MHz	1.VHF Communications (air-to-ground, air-to-air) 2. VOR ground navigation stations 3. Instrument Landing System (ILS) 4. Marker Beacons (for ILS) 5. Emergency Locator Transmitters (ELT). Will be relocated to the UHF band.
Ultra High Frequency	**UHF**	300-3000 MHz	1. Distance Measuring Equipment (DME) 2. Tacan (Military navigation) 3. Glideslope (ILS) 4. Global Positioning System (GPS), U.S. 5. Glonass (Russia, similar to GPS) 6. Galileo (European Union , similar to GPS, under construction) 7. Transponder 8. Traffic Alert and Collision Warning System (TCAS) 9. Emergency Locator Transmitter (2nd generation to be implemented)
Super High Frequency	**SHF**	3-30 GHz	Air Traffic Control Radar, Airborne Weather Radar, Radar Altimeter,
Extremely High Frequency	**EHF**	30-300 GHz	Millimeter wave radar (for experimental enhanced vision systems)

Aviation radio began at the lower end of the radio-frequency spectrum. Nearly all communications and navigation before 1940 occurred on Low and Medium Frequencies because devices for higher frequencies hadn't been invented.

By the end of World War II (1945), advances in High Frequencies expanded avionics further up the spectrum.

Note that each band begins and ends with the digit "3". This was determined by international agreement to provide a global structure.

Frequencies which fall within any band behave similarly. Low frequencies hug the earth, following the curve over the horizon. Higher up, frequencies act like light---travelling in straight lines.

ergy. But their behavior varies depending on frequency (number of Hz per second) and wavelength.

Bands. Aviation services are inserted into segments called "bands," as determined by international agreement. Each frequency within a band may also be called a "channel."

Some aircraft bands border on other services. One navigation band (for VOR and ILS) begins at 108 MHz, just above the FM broadcast band (88-108 MHz). At the lower end of the radio frequency spectrum are aircraft beacon stations below 530 kHz, the beginning of the AM broadcast band. Such close spacing is important to know because interference to avionics often originates just outside the aircraft band. As recently as 2008, pilots reported interference from high-intensity signals emitted by FM broadcasters. These events forced the avionics industry to tighten specifications on radios to resist such interference but it is occasionally troublesome.

Low Frequencies

Disruption to aircraft radio from other sources is tied to where the signal occurs in the spectrum. For lower frequencies, VLF (Very Low Frequency), Low Frequency (LF) and MF (Medium Frequency) bands the aircraft receiver is more susceptible to electrical noise from generators, alternators, spark plugs and lightning from thunderstorms. This was especially difficult for pilots during the early days of instrument flying because all navigational aids (navaids) were low in frequency. These services, in fact, performed worst when needed most; at night and in areas of lightning and thunderstorms. Fortunately, avionics moved to higher frequencies which are far more resistant to such interference.

Radios working on low frequencies are also susceptible to "P-static"—(P for Precipitation). Electrical charges build on the skin of an airplane flying through snow, ice particles and other visible signs of moisture. Besides noise, it can also cause complete loss of signal in a Loran receiver, which operates low in the spectrum.

Low frequencies also suffer from "shore effect." When they move between land and water, the difference in conductivity speeds or slows the radio wave. This bends the wave, causing the aircraft receiver to see the signal arriving from a different angle. The result is navigational error.

There is also "night effect", troublesome to the low frequencies of ADF (automatic direction finder.) It's caused by "skipping," a phenomenon that carries signals from hundreds or thousands of miles away, causing interference to the desired station. It's the same problem you hear at night on an AM car radio; stations from across the country, silent during the day, arrive at great strength and compete with local stations. In an

Higher Bands: *Named by Letters*

Microwave Bands

Name	Frequency
L Band	1 to 2 GHz
S-Band	2 to 4 GHz
C Band	4 to 8 GHz
X Band	8 to 12 GHz
K*u* Band	12 to 18 GHz
K Band	18 to 26 GHz
K*a* Band	26 to 40 GHz
Millimeter Wave Bands	
Q Band	30 to 50 GHz
U Band	40 to 60 GHz
V Band	46 to 56 GHz
W Band	56 to 100 GHz

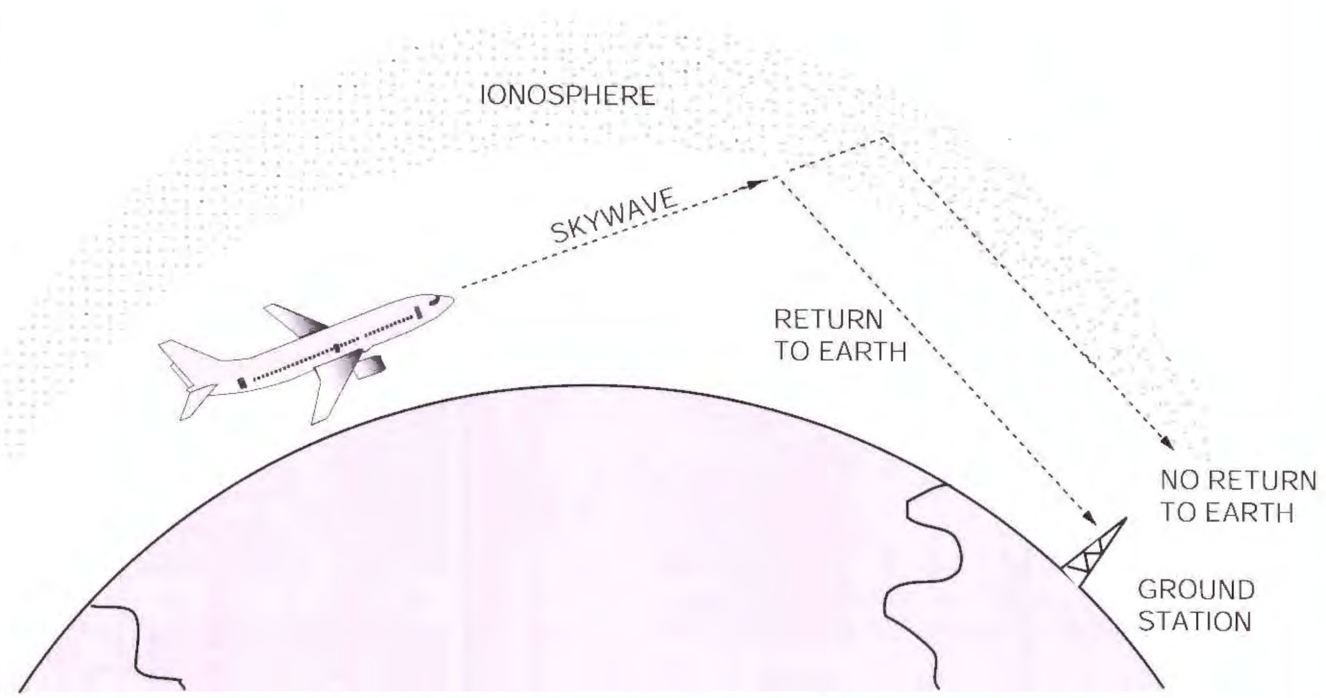
When frequencies rise above 1 GHz, they are further divided into bands identified by letters. Because wavelengths are so short, they are termed "microwaves," and are measured in a few inches or centimeters.

Microwaves are valuable because the radio signal penetrates haze, snow, clouds and smoke. For detecting thunderstorms, weather radar operates on microwave frequencies which reflect from rainfall. Several services depend on the fact that microwaves travel in straight lines; GPS, radar, DME and transponder, for example.

Another property of microwaves; they can be focussed into a beam with a small antenna. This provides sharp images for radar weather, and broadband for TV, Internet, and data services between airplane and satellites.

Above the microwave region are shorter signals of Millimeter Wave Bands. One of the first applications in avionics is the "Enhanced Vision System," which creates runway images for low-visibility landings.

Skipping Through the Ionosphere



The High Frequency (HF) band communicates across oceans and remote areas by "skipping" through the ionosphere. Radio signals leaving the aircraft reflect after striking ionized layers of air from about 60 to 200 miles high. Because HF signals hardly touch the earth, they lose little strength. However, angles must be correct for the signal to reach the ground station. Created by the sun's ultraviolet radiation, the ionosphere rises and lowers each day. Different frequencies reflect at different angles so the pilot selects the most favorable HF channel. Some frequencies will not bend enough and never return to earth (at certain times of the day), as shown by the skywave at the upper right; see "No Return to Earth."

HF radio is congested and sometimes difficult to use. It will be replaced by satellite communications, which move through the ionosphere with little effect.

aircraft ADF (Automatic Direction Finder), it causes the pointer on the instrument to wander, flutter and have difficulty locking on to the NDB (Non-Directional Beacon) station.

High Frequencies

High Frequencies (HF) played a major role in long-range navigation because they once were the only way an aircraft over an ocean or remote area could communicate to a land station. The long-distance capability of HF arises from "skip", as shown in the illustration.

Although HF sends signals thousands of miles, it has shortcomings. For HF to "hop" from the aircraft antenna and strike the desired ground station, the angles must be correct. And the ionosphere is hardly cooperative. Created by ultraviolet rays striking the top of the atmosphere it is in constant change. As the sun rises the ionosphere thickens (grows deeper)—then, after sunset, it thins out. This has the effect of lowering and raising the bottom of the ionosphere from about 60 to 200 miles above the earth. Not only does this cause a daily variation in skip angles, but there is also an 11-year sunspot cycle that interferes with signals.

HF radios try to solve this several ways. A pilot can select among a half-dozen or so HF frequencies to find a path where ionospheric conditions produce the correct angle to reach the distant station. HF radios also have automatic tuners which quickly adjust the antenna to a selected frequency. The HF band, however, has always irritated pilots because it doesn't provide the instant connection of other radio services. Adding to the problem is a shortage of HF frequencies, causing crowding on the channels.

There was an attempt to improve HF by replacing (analog) voice with digital signals. After years of development a system became practical but HF will eventually be replaced by satcom, which now provides instant contact anywhere on the globe.

VHF Band

Very High Frequency offers many improvements over lower frequencies. It has excellent immunity to electrical interference, thunderstorms, P-static, strobe lights and sparks from rotating machinery aboard the aircraft. Within its band, VHF provides hundreds more channels than lower frequencies. It is not affected by "night effect" and meets the navigational requirement of traveling in straight lines.

VHF, on the other hand, has limitations. Most important, it is line-of-sight; it does not follow the curve of the earth. The range of a communications (com) or navigation (nav) signal mostly depends on the altitude of the aircraft. A Cessna at 3000 feet will "see" a VOR ground station at about 50 miles; an airliner at 39,000 feet picks it up at about 200 miles.

L-Band

What is becoming the most important part of the radio spectrum for aviation is the L-band (1-2 GHz). At these ultra high frequencies, bands are named by letters.

L-band has long been the region for DME and transponder, now joined by GPS as the major L-band service. Signals easily penetrate rain, cloud and fog, which is essential for all-weather navigation.

Future Bands

Major changes will affect both radionavigation and radiocommunication. Frequencies are in short supply and there is competition among countries of the world to use them for purposes other than aviation. This is causing a worldwide shift to satellites for both navigation and communication. Because of the large bandwidth at the higher end of the radio spectrum, many more channels are available, as well as techniques to squeeze more information into digital messages, rather than voice.

The only challenge to radionavigation has been by inertial reference systems (IRS). In their first generation, they used "spinning iron" gyroscopes and other devices to provide navigational guidance. The equipment, however, requires much maintenance. A major improvement is the laser gyro, which uses light beams and no moving parts; the gyro's are aboard most airliners of the current generation equipped with EFIS.

Laser gyros's, however, are limited to en-route navigation because their error (about one nautical mile per hour) cannot allow precision landings. Also, an inertial system must be loaded with a known position at

From Hertz (Hz) to Gigahertz (GHz)

The unit of frequency is the hertz (Hz), or cycles per second. It ranges from about 20 Hz, the low range of human hearing, up through trillions of Hz, where waves behave like light.

1000 Hz = 1 kilohertz (1 khz)
1 million Hz = 1 megahertz (1 MHz)
1 billion Hz = 1 gigahertz (1 GHz)
1 trillion Hz = 1 terahertz (THz)

To convert hertz to kilohertz, move the decimal three places to the left:

1000 Hz = 1 khz

To convert kilohertz to megahertz, move the decimal three places to the left:

3000 khz = 3 MHz
200 khz = .2 MHz

To convert megahertz to gigahertz; move the decimal three places to the left.

100 MHz = .1 GHz

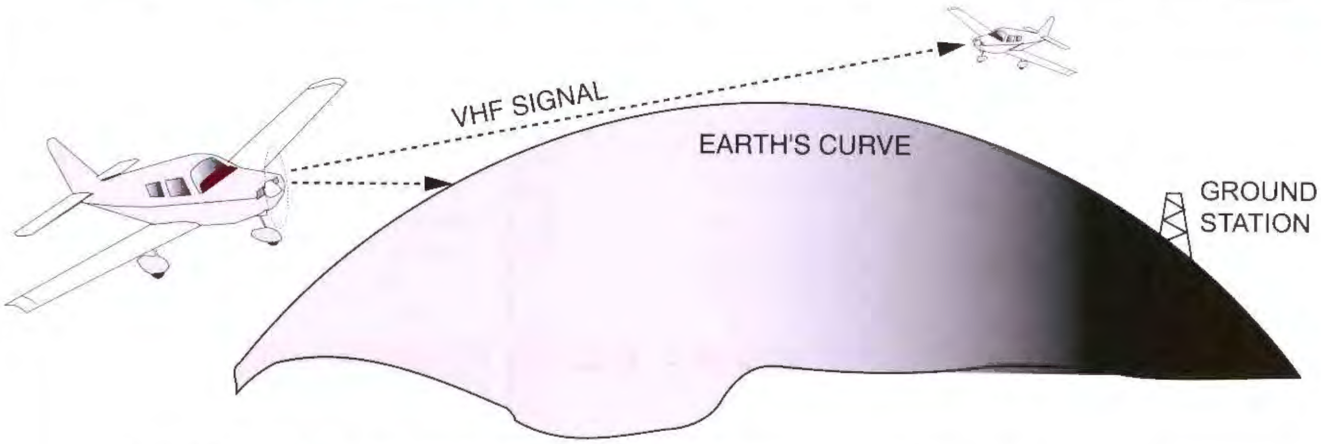
How the term hertz is applied for radio frequencies is shown in bands and frequency charts in this chapter. Other common frequencies in avionics include:

300 - 3000 Hz: The range of audio frequencies for voice communications. It's a narrow range compared to high fidelity used for music recording because that would broaden the signal and cause interference on adjacent channels. Researchers found that most of the ability to hear the human voice is in the 300-3000 Hz range.

400 Hz: In large aircraft, 400 Hz is the frequency for distributing power, much like 60 and 50 Hz are for power distribution in homes. Using 400 Hz in aircraft reduces the size and weight of power components.

90 Hz and 150 Hz are found in the ILS system for carrying navigational signals of the localizer and glideslope.

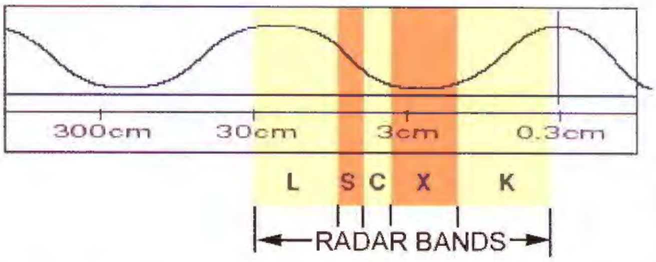
Line of Sight Communications



Signals in the VHF and higher bands travel in straight lines, with little effect from earth or ionosphere. This includes signals for VHF com and nav, GPS nav, transponder, DME, radar and other services above 30 MHz. Thus, the airplane at the left cannot communicate with the ground station on the far right because the signal is shaded by the earth. The two airplanes, however, can communicate because they "see" each other above the earth's horizon.

the beginning of a trip and updated against other known positions during long trips. GPS, on the other hand, not only finds itself in minutes almost anywhere on earth, but is far more accurate.

New navigation systems based on extremely high frequencies in the "millimeter bands," where radio waves take on the properties of light, are in development. They will create runway images (synthetic vision) for landing, solve the long-term problem of clear air turbulence and provide other services not possible on lower frequencies.



These portions of the microwave bands (L,S, C, X, and K) are used by radar for weather detection, ground mapping and other images. Many weather radars aboard civil aircraft operate in the X band

Control and Display of Bands and Frequencies

This stack of control-display units are found on airline instrument panels and represent five different bands of operation. Knobs marked "TFR" mean "transfer"---which takes a frequency stored in one window and transfers it to the active position ("ACT"). All the controls shown here conform to the ARINC 500 characteristic.

VHF - NAV

1. This is a combined control head. The left half is "VHF," and selects frequencies in the VHF communications band. In some radios, "Com" is used instead of "VHF."

Navigation on VOR or localizer frequencies is selected by the knob at the right, under "NAV." (The localizer is part of the ILS, Instrument Landing System.)

DME

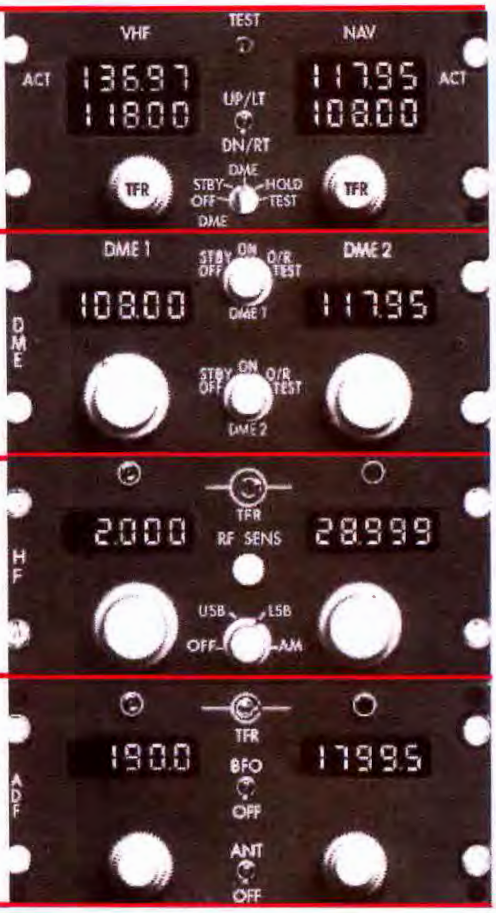
2. This control head selects stations in the DME band, but frequencies shown on the dial (108 and 117.95) are *not* DME frequencies. They are VOR (nav) frequencies. Because DME stations are paired with VOR stations, selecting a VOR automatically "channels" the DME.

HF

3. A control head for a High Frequency (HF) radio, used for long range communication. Each frequency, or channel, is selected to operate in one of three modes; USB (Upper Sideband), LSB (Lower Sideband) or AM, (Amplitude Modulation), an earlier form of transmission.

ADF

4. The Automatic Direction FInder (ADF) has a control known as a "BFO," for "beat frequency oscillator." It is switched on to identify the station in countries which do not transmit an audio ID tone. The BFO makes the ID audible (in Morse Code).



Sigma-Tek

Aviation Frequency Assignments

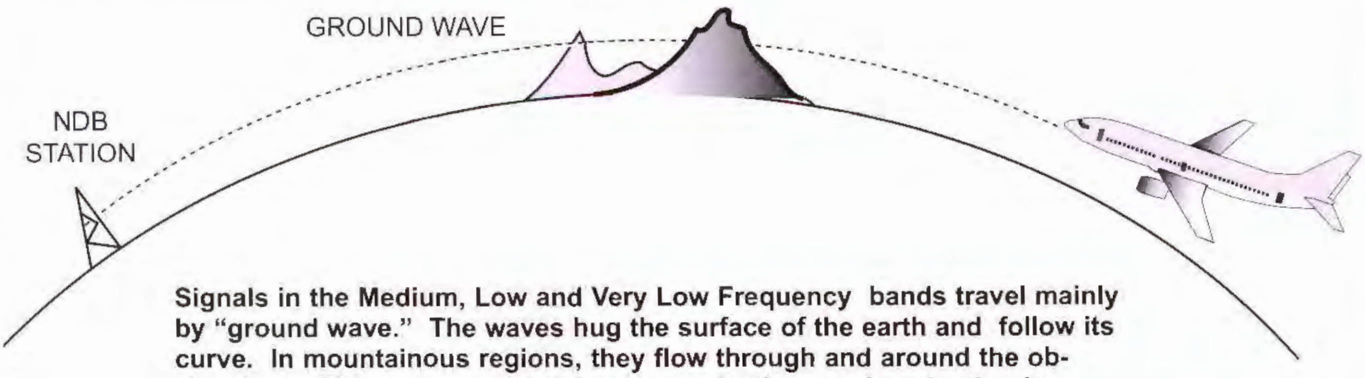
Navigation (Markers, VORs, ILS Localizers, VOR/ILS Test)

75 MHz	Transmitting frequencies of fan markers, Z markers, and ILS markers.
108.0 to 108.05 MHz	Commonly used for VOR ramp testers.
108.1 to 108.15 MHz	Commonly used for ILS localizer ramp testers.
108.2 to 111.85 MHz	Transmitting frequencies of VORs. Operated on even tenths.
108.3 to 111.95 MHz	ILS localizers with or without voice. Operated on odd tenths.
112.0 to 117.95	Transmitting frequencies of VORs.

Communications (Air Traffic Control, emergency, advisory, support, ARINC, air-to-air, flight schools flight inspection, military advisory, manufacturer test, special use)

118.0 to 121.4 MHz	ATC
121.5 MHz	Emergency frequency (search and rescue-SAR), emergency locator transmitter (ELT) signals (five-second operational check)
121.6 to 121.925 MHz	Airport ground control, ELT test
121.95 MHz	Aviation support
121.975 MHz	Private aircraft advisory (FSS)
122.0 to 122.05 MHz	FSS EFAS (Flight Watch)
122.075 to 122.675 MHz	Private aircraft advisory (FSS)
122.7 to 122.725 MHz	Unicorn, non-tower controlled airports
122.75 MHz	Air-to-air communications (fixed wing aircraft)
122.775 MHz	Aviation support
122.8 MHz	Unicorn, non-tower controlled airports
122.825 MHz	Aeronautical en route (ARINC)
122.85 MHz	Multicom
122.875 MHz	ARINC
122.9 MHz	Multicom, SAR training, airports with no tower, FSS, or unicorn
122.925 MHz	Multicom, special use (forestry management/fire suppression, fish and game management/protection, etc.)
122.95 MHz	Unicorn, tower-controlled airports, airports with full-time FSSs
122.975 to 123.0 MHz	Unicorn, non-tower controlled airports
123.025 MHz	Air-to-air communications (helicopter)
123.05 to 123.075 MHz	Unicorn, non-tower controlled airports
123.1	SAR, temporary control towers
123.125 to 123.275 MHz	Flight test stations of aircraft manufacturers
123.3 MHz	Flight schools
123.325 to 123.475 MHz	Flight test stations of aircraft manufacturers
123.5 MHz	Flight schools
123.525 to 123.575 MHz	Flight test stations of aircraft manufacturers
123.6 to 12.65 MHz	Air carrier advisory (FSS)
123.675 to 26.175 MHz	ATC
126.2 MHz	Military common advisory
126.225 to 128.8 MHz	ATC
128.825 to 132.0 MHz	ARINC
132.025 to 134.075 MHz	ATC
134.1 MHz	Military common advisory
134.125 to 135.825 MHz	ATC
135.85 MHz	FAA flight inspection
135.875 to 135.925 MHz	ATC
135.95 MHz	FAA flight inspection
135.975 to 136.075 MHz	ATC
136.1 MHz	Future unicorn or AWOS
136.125 to 136.175 MHz	ATC
136.2 MHz	Future unicorn or AWOS
136.225 to 136.25 MHz	ATC
136.275 MHz	Future unicorn or AWOS
136.3 to 136.35 MHz	ATC
136.375 MHz	Future unicorn or AWOS
136.4 to 136.45 MHz	ATC
136.475 MHz	Future unicorn or AWOS
136.5 to 136.975 MHz	ARINC

Ground Wave Transmission



Signals in the Medium, Low and Very Low Frequency bands travel mainly by "ground wave." The waves hug the surface of the earth and follow its curve. In mountainous regions, they flow through and around the obstructions. This produces steady communications and navigation because signals are not blocked by the horizon. Although these bands were the first to be used by avionics, they will disappear and be replaced by satellite communications and navigation. Low frequencies have many limitations, including; great susceptibility to electrical interference (natural and man-made), few channels and lack of global range. Services now on low frequencies are ADF (Automatic Direction Finder), Loran and, until recently, Omega (which has been decommissioned).

Review Questions
Chapter 26 Bands and Frequencies

26.1 A radio wave travels at the rate of ____________.

26.2 Aircraft communication frequeneies between 118-137 MHz are in the _______band.

26.3 Satellite navigation, on approximately 1.5 GHz (1500 MHz) are in the _______ band.

26.4 What problems made lower-frequency bands--VLF, LF and MF----difficult to use in aviation?

26.5 Frequencies in the HF band are able to "skip" long distances. What is the name of the HF signal that leaves the antenna, reflects off the ionosphere and returns to earth?

26.6 How many kilohertz (kHz) equal 3 MHz (megahertz)?

26.7 Frequencies below the Medium Frequency Band mainly travel via ___________ waves.

26.8 The localizer frequency in an ILS system operates within the band 108.3 to 111.95 MHz. How are localizer frequencies assigned within the band?

Chapter 27

Antenna Installation

A light aircraft that occasionally flies on instruments ("light" IFR) typically has these antennas:

Com 1	DME
Com 2	GPS
VOR	ADF Loop
Localizer	ADF sense
Glideslope	Marker Beacon
Transponder	Emergency Locator

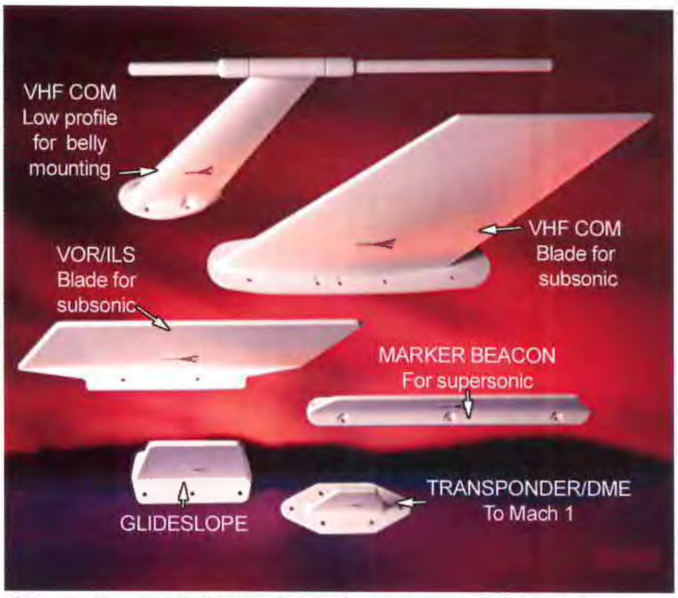
For low IFR (low ceilings, extended flight in clouds) a well-equipped General Aviation airplane may add antennas for:

Weather detection (Stormscope)
Traffic detection (TCAS I)
Datalink for weather (XM radio, WSI)
Antenna for emergency handie-talkie

Airliners and corporate aircraft carry most of the above, plus antennas for:

Weather radar
TCAS II (collision avoidance)
Satcom (satellite communication)
Radar altimeter
Passenger telephone and entertainment

Not mentioned above is Loran, a popular navigation system that rapidly declined with the arrival of GPS. Loran does not cover the world and suffers interference from precipitation. Loran, however, is still aboard many light aircraft---which means there is a need for replacement antennas. The installation of a Loran antenna is the same as that described for a VHF com.



Antennas by HR Smith for high-performance aircraft are encased in thermosplastic composite material to resist rain erosion, impact, chemicals and temperature changes.

In 1971, a system known as Omega provided world-wide long-range navigation. But with the rise of GPS, Omega lasted only until 1997, when its eight global stations were taken off the air. Omega antennas were difficult to install because the airplane had to be "skin-mapped---tested all over to find an electrically quiet place that would not interfere with the Omega signal.

Antennas for Airline,Corporate and Military Aircraft

VHF Com, will operate a power rated at at 100 watts. Has internal duct for hot air de-icing. Used on Boeing, Lockheed and Douglas.

VHF Com with low profile. Has filter to prevent VHF interference to GPS receiving antenna.

Glideslope antenna rated for Cat III (instrument) landing. Used on Gulfstream, Regional Jet, others.

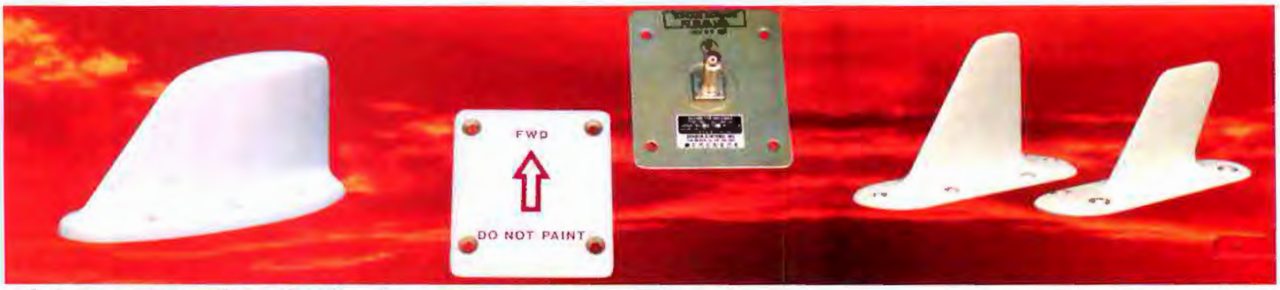
UHF com antenna for military aircraft covers 180-400 MHz. Rated to 70,000 ft and 35 G's

TCAS (collision avoidance) antenna determines direction of target. Arrow shows antenna mountng direction.

Directional antennas for TCAD (collision avoidance) system. Mounts on top and bottom of fuselage.

GPS models may look the same but some have built in preamplifiers to overcome losses in long cable runs

This amplified GPS antenna is aboard Boeing aircraft for GPS reception in multimode receivers.



Satcom antenna for operating in Aero-L and Aero-C bands of INMARSAT satellite. It is a low-gain antenna for moving data on 1.5-1.6 GHz.

Outside and underside views of radio altimeter antenna. Operating on 4200-4400 MHz, it is flush-mounted on belly of aircraft.

Antennas for passenger radiotelephone service operating on 830-900 MHz.

VHF-FM com antenna for 140-180 MHz (outside the aviation bands). Provides communications with non-aviation services.

Two different marker beacon antennas (75 MHz). Top one is a flush-mount used on the Boeing 747. Bottom one is low-profile, used on the Boeing 737 and Pilatus.

ADF antenna contains both loop and sense antennas for automatic direction finder. Applications include several Boeing, Douglas and Airbus airliners.

Sensor Systems

Two blades, known as a "balanced loop," mount on rudder fin to provide VOR, localizer and glideslope reception.

Hostile environment. Aircraft antennas operate under the worst conditions. Sitting on the ramp in Arizona on a summer day, they bake in over 100 degrees F. After the airplane takes off and reaches altitude 15 minutes later, antennas are chilled to 50 degrees F below zero and buffeted by winds over 500 kts. If the airplane flies in clouds at or near the freezing level, ice may form on the antenna. And it's not the *weight* of the ice, but the change in antenna shape that causes "flutter," a vibration that can break the structure. As if that weren't enough, the antenna is mounted on an aluminum fuselage which flexes as the airplane pressurizes. Add such hazards as fluid sprayed on the airplane for de-icing or hydraulic oil in the belly and you can see why antennas require rugged construction and follow-up maintenance.

What goes wrong? Despite the hostile environment, most problems (antenna-makers say) result from poor installation. Materials used by every reputable antenna maker are tested and well-proven. It's the installer's responsibility to provide a good location, a secure mounting, a seal against weather and a low-

How to Read an Antenna Spec Sheet

First, consider the type of aircraft. Catalogs often divide them into such categories as General Aviation, Commercial (business jets), air transport (airline) and military. These categories are divided into type of service; communications, navigation, transponder, DME and others.

In the example shown here, we are seeking a communication antenna for a business jet. Looking down the list of specifications (see numbers in red);

1. Frequency. The aviation "com" band extends from 118 to 137 MHz. The band is also called "VHF" or "VHF com."

2. VSWR. Meaning "Voltage Standing Wave Ratio," VSWR indicates antenna efficiency. The lower the first number (2), the higher the efficiency. Manufacturers produce antennas with a VSWR usually less than 3.0:1.

3. Polarization. VHF com antennas operate with "vertical" polarization, which helps concentrate signals toward the horizon, rather than angling up to space.

4. Radiation Pattern. "Omnidirectional" sends signals in every direction, a requirement because the ground station may be anywhere.

5. Impedance. The AC electrical load of the antenna, 50 ohms, is standard in aviation. The cable feeding the antenna is also 50 ohms, which produces a correct match to the antenna.

6. Power. The amount of radio-frequency power that can be handled by the antenna. Light aircraft transmitters generate about 5 to 10 watts. A transmitter for an airliner or business jet may run 25 watts.

7. Connector. Many antenna connectors are the "BNC" (bayonet) type, but be sure the coaxial cable is also fitted with a BNC connector. TNC is also used.

8. Altitude. Rated to 50,000 feet, this antenna can operate at altitudes flown by a business jet. (The highest altitude for air traffic control is 60,000 feet.)

9. Air speed. The antenna can operate at 600 knots at 25,000 feet. This is accomplished by the "blade" design, which is stronger than narrow whips or rods for slower aircraft. Any requirement above 600 knots would be for military, or aircraft flying at supersonic speeds

10,11 Certifications. These ratings mean the antenna will meet environmental and performance standards for this application.

12. BNC The antenna accepts the common BNC connector used on most coaxial antenna cables.

VHF Blade Antenna

	MODEL	CI 223 VHF Blade Antenna
	Electrical	
1	Frequency	118 - 137 MHz
2	VSWR	2.0:1 Maximum
3	Polarization	Vertical
4	Radiation Pattern	Omnidirectional
5	Impedance	50 Ohms
6	Power	25 Watts
	Mechanical	
	Weight	1.5 lb. Maximum
	Height	12.5 in. Maximum
	Material	High Density Polyurethane
	Finish	Polyurethane Enamel
7	Connector	BNC (female)
	Environmental	
	Temperature	-55°C to +85°C
8	Altitude	50,000 ft
9	Air Speed	600 Knots @ 25,000 ft
	Federal Specifications	
10	RTCA Environmental	DO-160D
	Environmental Category	[D2X]ACB[R(C,C1)U(F,F1)] XWFDXSXXXXX[XX]X[XXXX]XAX
11	FAA TSO	C37d, C38d
	RTCA MOPS	DO-186A
	ORDER OPTIONS	
	Connector	
12	BNC	Standard
	Color	
	White	Standard
	Gasket	
		C22310

Comant

Antennas for Light Aircraft

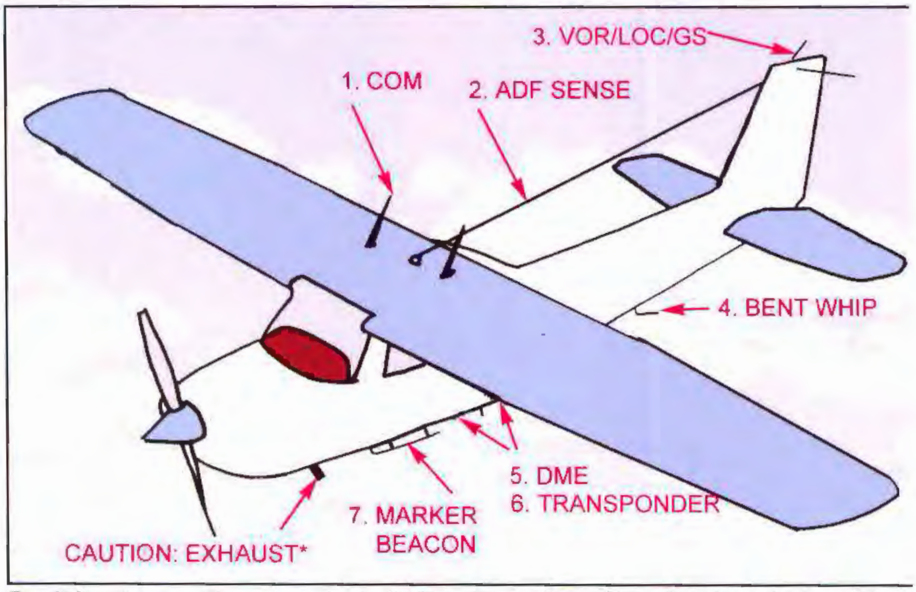
1.VHF com antenna, 118-137 MHz. It contains an aluminum radiator inside polyurethane foam.

3. "Cat's Whisker" VOR antenna found on most light aircraft. The round container at bottom is a"balun," which matches the coaxial cable to the V-shaped antenna rods. "Balun" means "balanced-unbalanced" (the antenna is balanced, the cable is unbalanced). The antenna also provides localizer and glideslope signals (see "couplers").

5- 6. Transponder and DME. The transponder antenna operates in the 1030-1090 MHz band to reply to interrogations from air traffic control. The tip of the antenna is a "corona" ball. If the antenna picks up static electricity, the ball discharges it with less interference than would a pointy tip. Height of the antenna is 3 inches.

A DME antenna is nearly identical to the transponder antenna in size and shape. It operates in the same UHF band, on frequencies 980-1220 MHz.

7. Marker Beacon antenna operates on 75 MHz and is 29 inches long. This is a "sled" type (it resembles a sled runner). If the antenna is enclosed, it's a "boat" type. Marker beacon antennas mount on the bottom of the aircraft to avoid shading the signal from the ground station.



Don't locate an antenna on the belly in line with an exhaust pipe. It becomes coated and discolored. Locate antennas as close as possible to the centerline of the fuselage, but avoid cutting into structure like ribs and stringers.

resistance electrical ground to the airframe---all factors covered in this chapter.

Selecting an Antenna

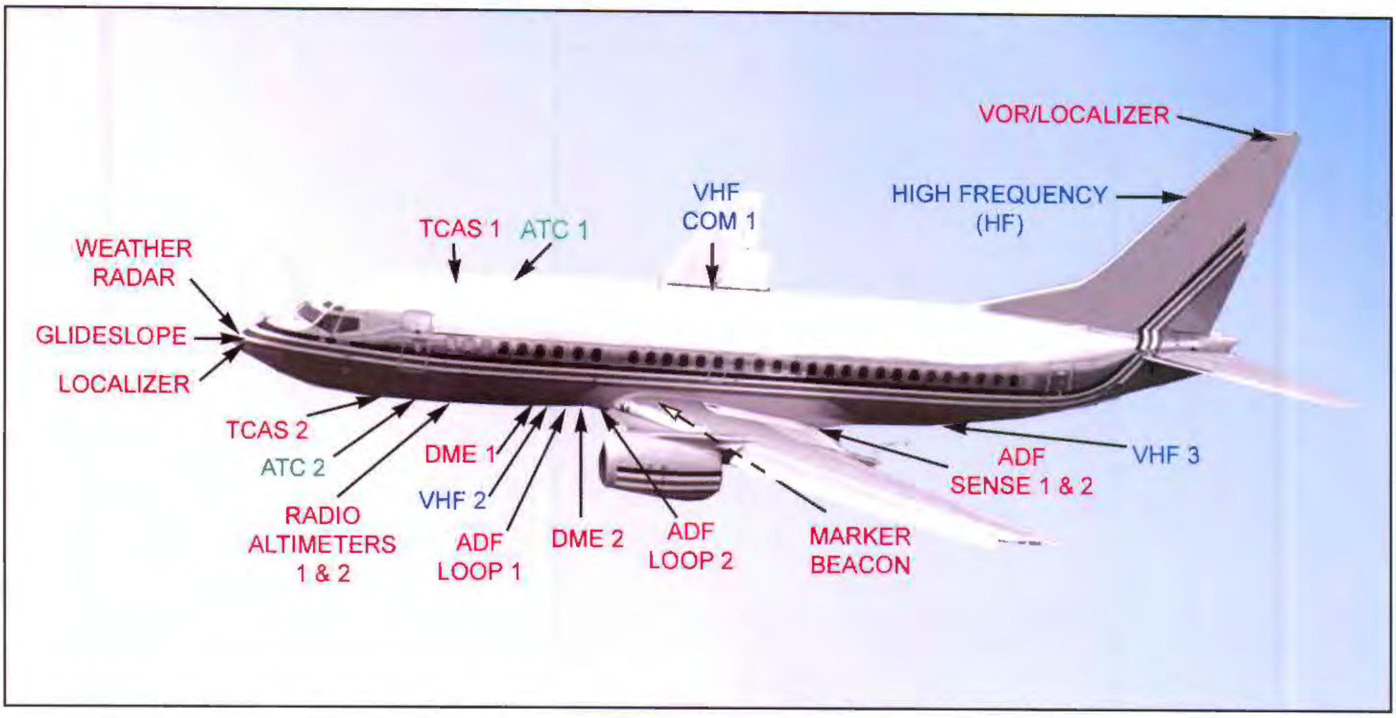
Catalogs on antennas are filled with engineering terms; *isotropic radiator, dB gain, VSWR, impedance,* and more. It is not difficult, however, to choose the right antenna for the job, so long as you select a model from a reputable antenna manufacturer---for example, Comant, Dorne & Margolin, Sensor Systems, RAMI and HR Smith---the antenna should perform as described for its category (airline, military, general aviation, etc.). An explanation of important antenna terms is shown in the table.

An antenna with a "TSO" (Technical Standard Order) assures the antenna was tested to the limit of its specifications. The TSO is not a legal requirement for many installations, but antenna makers obtain this certification as a mark of quality. Business and airline operators usually require it.

Major specifications to know are shown in the table, "How to Read an Antenna Spec Sheet." Consider other details in selecting an antenna:

Speed. A dividing line between antennas depends on the speed of the aircraft. For General Aviation look for the rated speed, which may be 350 kts, 450 kts, etc. Slow aircraft (under 200 kts) often use antennas which

Airline Antenna Locations



Shown above is a Boeing 737. Antennas divide into three categories, often known as CNI, for Communication, Navigation and Interrogation. Navigation antennas are shown in red, communications in blue. The two interrogation antennas (green) are for ATC, which is the airline term for "transponder."

Most antennas are dual installations because safety requires two or more radios for each function. Where possible, they are placed at top and bottom of the fuselage for greatest reliability.

The two radar altimeters must be at the bottom because they measure the few feet between the airplane belly and runway during a low-visibility landing (Category 2 ILS and higher).

In the nose are three antennas protected against weather by a plastic radome. The glideslope antenna in small aircraft is usually on the tail (as part of the VOR antenna). In large aircraft, however, the glideslope antenna is usually in the nose. During an approach, large aircraft pitch up at a high angle of attack, which could cause its wings and fuselage to block glideslope signals arriving from the ground. Putting the glideslope in the nose eliminates that problem.

New airline models add several more antennas; GPS for navigation and satellite (for voice and data).

are simple rods or whips. They are not sturdy enough for speeds of high-performance piston and turbine aircraft, so the antenna is encased in a fin-like shell filled with plastic or composite material. Some housings are sufficiently rugged to be rated for the Mach speeds of military aircraft.

Altitude. Antennas are rated for altitude. Non-turbocharged airplanes usually have a service ceiling around 20,000 feet. When turbocharged (with piston engines) they cruise in the low 20,000's and higher. Turboprop aircraft fly in the 30,000-ft range, while pure jets climb into the 40's.

For most single-engine aircraft, com 1 and 2 antennas are located atop the cabin. Try to space them at least 36 inches apart to reduce interaction. This could reduce reception and transmission in certain directions.

Connectors and Cable. Other items to check on the spec sheet are the cable and connector. If coaxial cable is not supplied with the antenna, check the type of connector at the base of the antenna---BNC, TNC or other. You'll need to match that connector when you make up the cable.

Antenna Types

VHF Com. Communications antennas in the VHF band (118-137 MHz) come in different models depending on airspeed. Slow aircraft can operate with a simple stainless steel rod. Faster aircraft need a rigid housing, often in the form of a blade. If you need to mount an antenna on the belly of a small aircraft, consider a "bent whip," which gives extra ground clearance.

VOR antennas. There is no power rating for the VOR antenna because it receives only low-level signals. Most light aircraft use the "cat's whisker," a V-shape antenna that mounts atop the rudder fin. For best operation, the open side of the V should point forward (which favors reception ahead of the airplane).

In the description of a VOR antenna, look for the word "balun." It means "balanced-unbalanced," referring to the fact that the antenna is "balanced," but the coaxial cable feeding it is "unbalanced." The balun is a small transformer which matches "balanced to unbalanced". In some VOR antennas, the balun is supplied inside the antenna.

Technicians once made their own baluns with lengths of coaxial cable, so these devices may re-appear if you open up an old airplane. The ready-made balun transformer is an easier solution.

Slow airplanes use the cat's whisker for VOR reception, but faster aircraft need added structural strength. As shown in the illustrations, this is accomplished with "towel bar" or "balanced loop" VOR antennas. These models also perform better during "RNAV" (area navigation); they are more efficient at receiving VOR stations to the right and left of the aircraft, rather just fore and aft. Airplanes once flew only toward or away from VOR stations, but RNAV receivers pick a VOR signal off one wing and electronically

Com antenna on the bottom of a helicopter tail boom. Because of the main and tail rotor blades, antenna locations on helicopters are more difficult to find.

VHF com antennas are usually placed top and bottom, as in this King Air, when the aircraft is certified for flight in icing conditions. Ice on an antenna may cause vibration and breakage. It is unlikely that both top and bottom antennas will be affected the same way because of different slipstreams.

Comant

VOR "blade" is a strong, low-drag antenna for turbine-powered aircraft. With a blade on either side of the rudder fin, it is sensitive to VOR ground stations to the left and right of the aircraft course. This improves signals for area navigation (RNAV).

move it ahead of the airplane.

The VOR antenna in airliners is often hidden inside a fairing on the forward part of the rudder fin. Made of composite material, the fairing allows signals to pass through while protecting the antenna against weather.

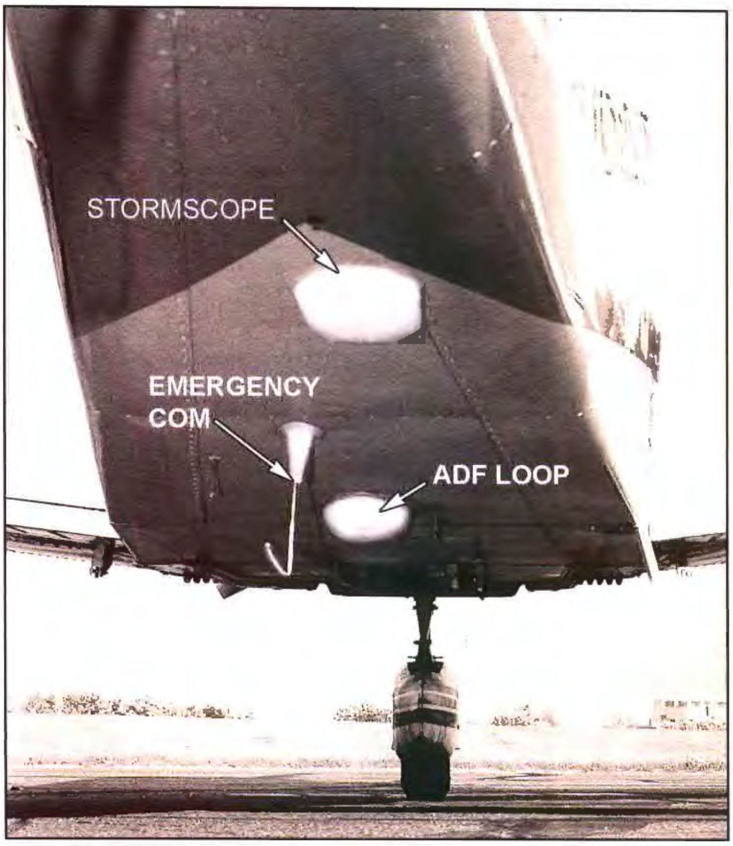
Experimental and home-built aircraft often hide their antennas inside fuselage or wings because these airplanes are sometimes made of composites. However, some composites contain carbon fibers which block radio waves and rule out hidden antennas.

HF antennas. High Frequency antennas (for long range communications) began as a trailing wire reeled out by the pilot through a hole in the rear of the airplane. The length was adjusted to the frequency. With the development of antenna tuners, which electrically shorten or lengthen the wire, the HF antenna became a fixed wire strung from the tip of the rudder fin out to a wingtip or cabin roof. As big jets went into service, the HF antenna became a horizontal mast pointing forward on the rudder fin (as on the Boeing 707). HF antennas are now hidden behind plastic fairings and automatically tuned when the pilot selects a channel.

Location

The position of an antenna on an airframe greatly affects its life, performance and reliability. If the airplane is in corporate or air transport service, the airplane-maker has already determined the best antenna locations, so follow his guidance. Locations were carefully engineered and certified. If an antenna becomes defective, a replacement goes in the same location.

There are instances where new avionics are added to old airplanes and require new antennas. Again, if it



Belly of a single-engine aircraft. Stormscope antenna is for weather (lightning) detection. The ADF loop is forward. Between them is a "bent-whip" com antenna to connect a handie-talkie during radio or electrical failure. Some pilots also use it to listen for clearances while waiting on the ground with the engine off.

Notice that none of the three antennas straddles the center line of the airplane. Each is offset slightly to avoid cutting into a longeron, rib or other framing member.

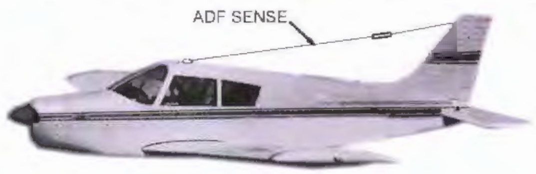
is a large airplane, the manufacturer determines the location of the new antenna. He may have obtained an STC (Supplemental Type Certificate) which has engineering drawings of how and where the antenna is installed.

Never cut into the skin of a pressurized aircraft unless you have approved guidance material. Special techniques are required to keep the airframe air tight and weather proof.

For light aircraft in General Aviation, there is less guidance on antenna location. A starting point is using the same location already selected by the manufacturer for the airplane you're working on. If that's not practical, consider some recommended practices.

One precaution; walk around the tie-down area of almost any airport and you will see airplanes with poor antenna locations. The biggest mistake is putting antennas too close together---so don't use any aircraft as a model without considering some basic rules.

Flat base. Antennas work best when mounted on a flat surface. This keeps the rod or blade type pointing straight up. Little GPS antennas should lie horizontal for good 360-degree pickup. If an antenna is tilted, it will not operate equally in all directions. One exception



ADF sense antenna on old aircraft is suspended between tail fin and top of cabin. The fitting on the wire contains a spring for taking up slack. By the 1990's, the outside sense antenna disappeared in new installations; it is now inside the ADF loop antenna housing, which is usually mounted on the belly.

ADF sense antenna mounts above the cabin of a light aircraft. It consists of a long wire, tension device to keep the wire from sagging and a cabin-top feedthrough to bring the cable inside the aircraft.

Nose cone is lifted on a corporate jet to reveal glideslope antenna. Weather radar antenna is inside the cone. Above glideslope is the weather radar transmitter-receiver.

is the "conformal" antenna, which is shaped to fit a curve on the airframe. Examples are shown in the chapter on satellite communication.

If an antenna is mounted on a slight curve on the fuselage, the manufacturer may provide a gasket to fill the crack between antenna base and aircraft skin. Don't overtighten mounting screws to eliminate the crack because deforms the aircraft skin. Some manufacturers offer a "mounting saddle" to match the base of an antenna to a deep curve. Even on flat surfaces there will be tiny cracks, but these are filled by a sealant.

Obstructions. Try to locate an antenna where it is not shaded by aircraft structure. This grows more important as frequency is higher; for DME, transponder and GPS, for example. A landing-gear door might block part of the signal on approach to landing, a critical phase of flight.

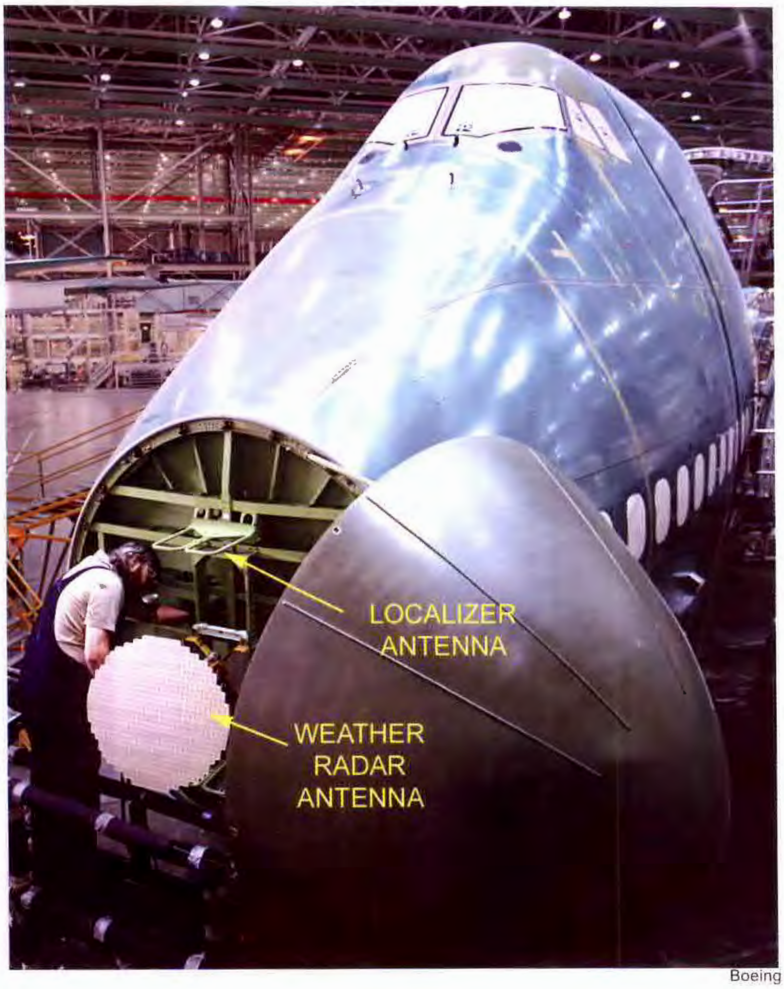
Spacing. Position antennas at least 36 inches apart. When com antennas are closer they interact and warp the signal pattern. The pilot notices this when he can't communicate the same distance in all directions.

If the antenna goes on the airplane belly, don't place it in a direct line behind an exhaust pipe. It will soon become covered with soot and scorched.

Hidden Structure. Even if you have an installation manual with the exact location of the antenna, always conduct your own survey. Look inside the skin where the antenna will mount to check for wiring harnesses, fuel lines, hydraulic pipes or other vital parts which could be struck by your drill.

Beware of the ribs, stringers and other primary structure of the airplane. Cutting them weakens the airframe. If there are no other antenna locations, you will need the services of a DER (Designated Engineering Representative) for the solution. Some shops employ a "structures" DER on staff, while others hire their services for each project.

When a mounting location is selected, see if you



Boeing

Boeing 747 under construction. The nose radome is swung out for access to antennas; for localizer and weather radar.

Light aircraft usually place the localizer antenna on the tip of the rudder fin. But large aircraft approach at a high angle of attack, which would shadow a localizer antenna on the tail. The localizer antenna shown here is also on the Boeing 757/767/777 and Fokker 100.

The weather radar antenna also must have an unobstructed view ahead of the aircraft to "see" precipitation.

Although not shown, the glideslope antenna is usually placed in the nose for the same reason.

These antennas are protected from wind and weather by the radome, which is transparent to radio waves. Radomes operate in a hostile environment and need regular maintenance.

can reach (or crawl) inside the airplane to the area of the antenna base. You may need to install a doubler plate, attach an antenna connector or install strain relief for the cable from inside the airplane.

Doubler Plate

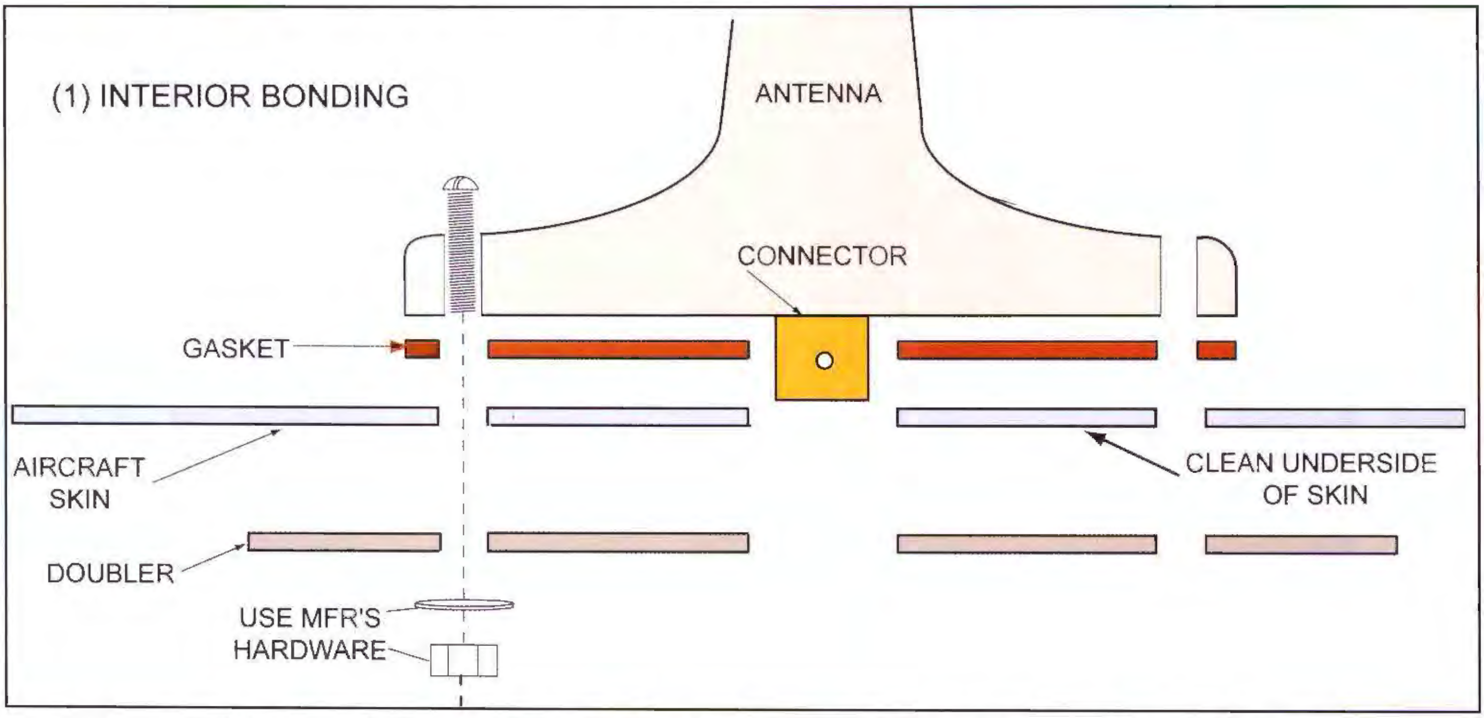
The thin skin of an airplane is not strong enough to support some antennas. To strengthen the mounting area, a metal plate, or "doubler," is installed under the skin, below the base of the antenna. Most VHF com antennas need such reinforcement, and smaller antennas for DME and transponder, as well.

Doublers (also called "backing plates") are available from three sources. Some antenna manufacturers provide them with the antenna; you can make one yourself from the drawing supplied with the antenna; or obtain a prefab doubler from an avionics parts distributor.

Examine the area under the skin, where the antenna will mount, and hold the doubler in place with your hand. Is it hitting any structure or components inside? It's alright to trim the doubler a small amount so it clears the obstruction---or move the antenna to a better location.

When a com antenna must be mounted on the belly of a light aircraft, use a "bent whip" to prevent striking the ground. Although not as efficient as a top-mounted antenna, the bent whip shown here was used for 10 years. It reliably communicated 50 miles in every direction at an altitude of 3000 feet,

Bonding the Antenna to the Airframe-1



In this approach, the antenna bonds through its mounting screws to the aircraft skin *inside* the fuselage. The inside area, therefore, must be clean and corrosion-free. After clean-up, apply Alodine to the bare skin to slow future corrosion.

The gasket keeps out moisture, vapors and contaminants. A bead of sealant is applied around the base of the antenna for further protection. In this mounting, the gasket does not have to be conductive.

Mark and Drill Antenna Location

Aluminum skin should *not* be marked with a pencil or other writing tool containing carbon. An investigation into one airline crash found that a row of rivets had been marked with an ordinary pencil. The pencil carbon interacted with aluminum, causing damage that led to the accident. A felt-tip marker is said to be harmless to aluminum.

Use the paper template supplied with the antenna to mark mounting and connector holes in the doubler (if it is not predrilled), or use the holes in the antenna base as a guide.

It's important to locate holes so the antenna is aligned with the fore and aft centerline of the airplane. This does not mean the antenna must be *on* the centerline and, in many instances, you cannot use the centerline because of primary structure below. That means the antenna is often offset slightly from the centerline---but be sure the antenna remains parallel to the centerline. You want the antenna to streamline with the wind and cause the least drag.

Hole sizes are shown on the installation drawing but common mounting screws are 8-32 or 10-32 stainless steel. Another consideration is the shape of the screw head; some antennas require a pan head screw, others call for a countersunk screw. Use the correct one to avoid damage to the antenna base.

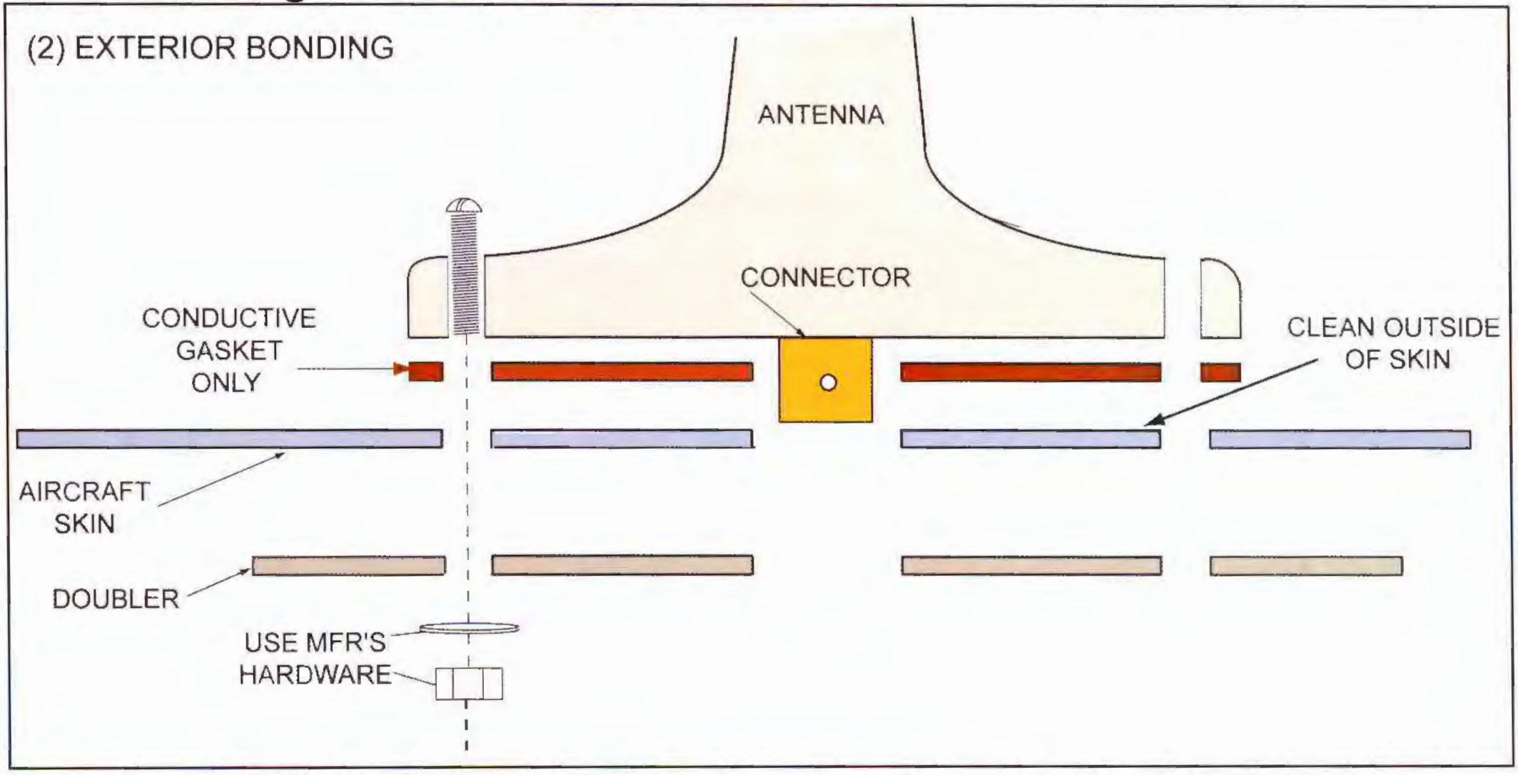
To prevent loosening, a lock washer and flat washer are placed under the nut. If locknuts are used, only a flat washer is needed. Before tightening the antenna, however, there's another important step.

Bonding

Creating a tight contact between two metal surfaces with the least electrical resistance is "bonding." It's important to bond the base of the antenna to the skin of the airplane for several reasons. Most important, many antennas depend on the airframe as part of their electrical length. Without this action, there may be loss of signal or unequal signal in different directions. Bonding also affords some protection against lightning strikes by allowing the charge to flow through the metal skin.

Many antennas are "DC-grounded," which means that normal antenna signals move in and out of the antenna, but lightning is shunted directly to ground (the airframe), where it usually produces little damage. Bonding also improves radio reception because it uses the airframe as a shield against interference. It also helps

Bonding the Antenna to the Airframe-2



In the exterior method, bonding is made to the outside skin. Thus, the skin must be cleaned and treated with Alodyne to prevent corrosion. Only a *conductive* gasket can be used with exterior bonding; there must be good electrical contact with the outer skin.

CAUTION: An antenna installation should be protected with sealant around the base and on the outside screwheads. Nuts or other mounting hardware inside the aircraft should also be sealed. This is important in pressurized aircraft. A well-sealed antenna prevents air and moisture from moving in and out of the fuselage during pressure changes in flight.

drain away static electricity that builds during flight.

There are two methods for bonding an antenna and both are recommended by antenna manufacturers:

1. Interior bonding (see illustration). In this method, nothing is done to the outside skin of the aircraft except to drill mounting holes. However, the skin *inside* the airplane is carefully cleaned of paint, grease or other coating. To prevent corrosion, the interior area (where the doubler goes) is treated with Alodyne.

When the antenna is mounted, the doubler is squeezed against the inside skin for bonding. The electrical connection between antenna and doubler is made through the mounting screws. If a gasket is supplied, place it under the base of the antenna before mounting. The gasket, incidentally, does not have to be electrically conductive; the connection is made through the screws

2. Exterior bonding. In this approach, the area for the antenna base on the *outside* skin is cleaned and treated with Alodyne. If a gasket is placed at the base of the antenna, it must be the *conductive* type to maintain electrical bonding between antenna and airframe. The doubler is mounted inside, as described earlier.

Mount the Antenna

Before placing the antenna in its mounting position, the job is simplified if you pull the inside coaxial cable through the connector hole in the skin to the outside and fasten it to the antenna.

Another technique is to replace the antenna mounting nuts with "Rivnuts" (if not already supplied by the antenna maker). Rivnuts are riveted to the doubler plate and have threaded inserts to receive screws. This eliminates the need for another person to climb inside the airplane to hold the nuts while a person outside tightens or loosens them.

When using Rivnuts you must countersink them into the doubler plate so they lie flush with the surface. To prevent weakening the doubler, countersunk holes should not go deeper than one-half the thickness of the doubler.

Mount the antenna by inserting its connector into its hole in the skin, and line up the front mounting holes. Place the doubler plate into position inside the airplane and insert the two front mounting screws. Next, install the rear mounting screws and tighten the screws enough to draw the antenna base, gasket (if present), airplane skin and doubler plate together. Don't overtighten the hardware and, if possible, use a torque wrench:

8-32 screws	20 in-lb
10-32 screws	23 in-lb

Never paint an antenna. This detunes it and can cause loss of coverage and weak signals. The factory coating is all that's needed. Some antennas (radio altimeter, for example) are so sensitive, they carry the warning, "Do Not Paint."

Seal the Edges Any mounting system may produce a good electrical bond, but there will be tiny openings or cracks around the antenna base that could admit water. Seal the antenna by running a bead of RTV silicone sealant around the base.

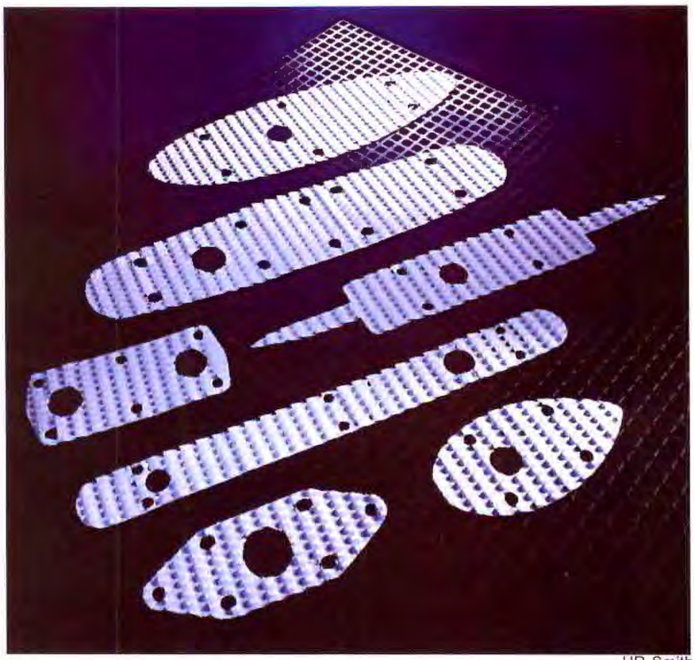
For demanding applications, the installer can choose a high-performance sealant, such as "AC-236 Class B." It resists fuel and other contaminants found around airplanes and is applied in two parts.

Low Resistance. To check the quality of a bonding job, manufacturers suggest placing a meter between a bare screwhead on the antenna base and clean aluminum skin next to it. The reading on an ohmmeter should not exceed .003 ohms. Unfortunately, ordinary shop multimeters will not read that low. An accurate measurement requires a *milliohmmeter.*

On the subject of resistance, be aware that you cannot check an antenna by placing the probes of an ohmmeter from the center pin of the antenna connector to the outer connector shell. Many antennas read zero ohms (a dead short) because they contain a transformer that grounds the antenna for static electricity and lightning. The normal antenna signal ignores the transformer. Testing an antenna requires other techniques, described in the chapter on troubleshooting.

Coaxial Cable for Antennas

Nearly all antennas are connected to aircraft receivers and transmitters through coaxial cable. It carries radio frequencies with high efficiency through a center conductor surrounded by one or more shields. An important characteristic of coaxial cable is "impedance," a term which describes its resistance to alternating currents (in this case, radio frequencies). The standard impedance for most coaxial cable in aircraft is 50 ohms. Most aircraft antennas are also rated at 50 ohms, which provides an excellent match. Unless impedances are the same, there is little transfer of energy between the antenna, cable and radio. When something causes a mismatch (a broken wire, short circuit, etc.) radio energy during transmit fails to reach the antenna and reflects back to the transmitter.



HR Smith

Conductive sealing gaskets fit between base of the antenna and airframe. Precut to size, they provide good electrical bonding.

The standard coaxial cable for avionics was RG-58 and there are still many miles of it in aircraft. But now it is ruled out for new installations because of a PVC jacket, which supports flame. Other coaxial cables, such as RG-400, have Teflon-based insulation that will not burn, as well as a double shield of copper braid for keeping desired signals in the cable and interference from getting in.

As frequencies rise higher in avionics equipment coaxial cable grows more important. When working with systems above the VHF band (satcom, satnav, TCAS and others) the manufacturer may call for a coaxial cable that performs more efficiently at higher frequencies. As shown in the illustration, never coil a coaxial cable tightly or its critical dimensions may change and cause losses.

As frequencies go higher, some manufacturers recommend RG-142 for coaxial cable. Typical applications include DME, transponder and UHF radiotelephones.

It's good practice to run RF coaxial cables separate from other wire bundles (which carry audio, DC power, data, etc.). RF cables usually contain heavy transmitter power that may induce interference into lower-level cables. Also, RF coaxial cables often carry weak receiver signals from the antenna, and are susceptible to picking up interference from other wiring.

Watch out for devices which require exact cable lengths. A "power combiner," which takes signals from a combined VOR/localizer/glideslope antenna, must have cables of exactly the same length. There are similar precautions for TCAS (collision avoidance), radar altimeters and other systems. These cables use their length as part of timing circuits so follow the manufacturer's precautions. Otherwise, run coaxial cables along the shortest practical route, but avoid sharp bends and tight coils.

Connectors. The most common connector for antennas is the bayonet-type BNC. If the application operates high in the radio spectrum, such as GPS, a lower-loss connector, such the TNC, is used. DME, transponders or UHF radiotelephone may also call for higher-performance connectors, such as TNC, C, N, or HN.

Duplexers. Although not commonly used, there is a device which enables two com transceivers to operate on one antenna. It has a switching arrangement that selects No. 1 or No. 2 transceiver. The circuit prevents the transmitted signal from one radio from overwhelming the receiver of the other, Most aircraft, however, have two separate VHF com antennas, which provide a backup if one antenna fails.

GPS Antennas

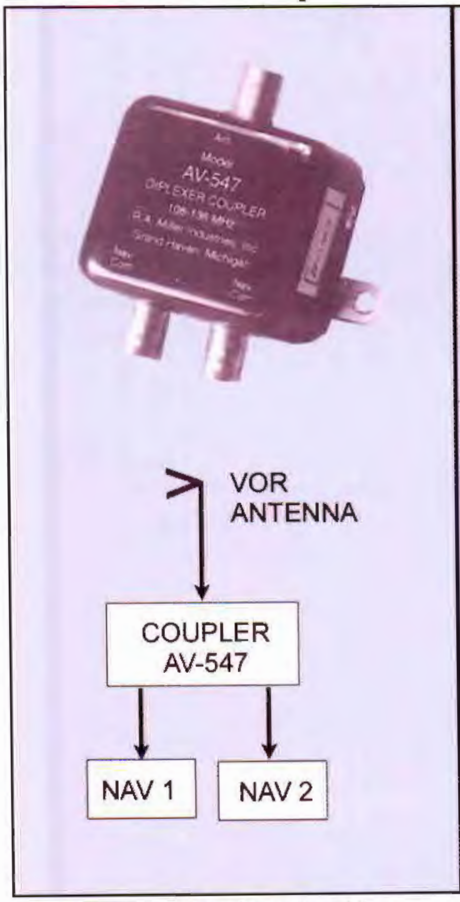
Antennas in the VHF band and below may install on the top or bottom of an airplane, but GPS antennas always mount on top. They need a clear view of the sky, as satellites rise from one horizon, climb to the zenith (overhead) then set on the opposite horizon.

Another reason for an unobstructed view is that GPS signals are extremely low in strength. Their frequencies are in the UHF band, where signals are easily shaded or reflected by aircraft structure.

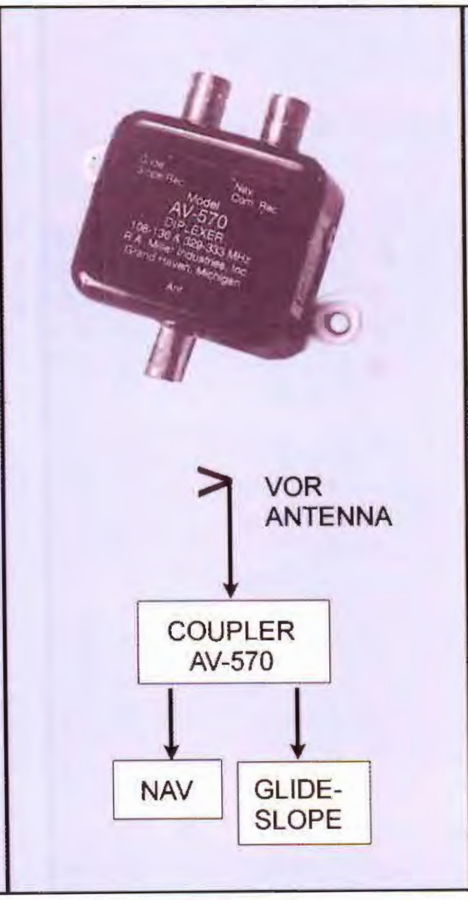
A GPS antenna must lie flat. If mounted on a tilt, it will not "see" satellites low on the horizon.

No matter what location you choose there will be some obstructions at certain angles (a tail fin, a raised wing, etc.) but this is usually not critical. The GPS receiver typically gathers information from six or more satellites always in view.

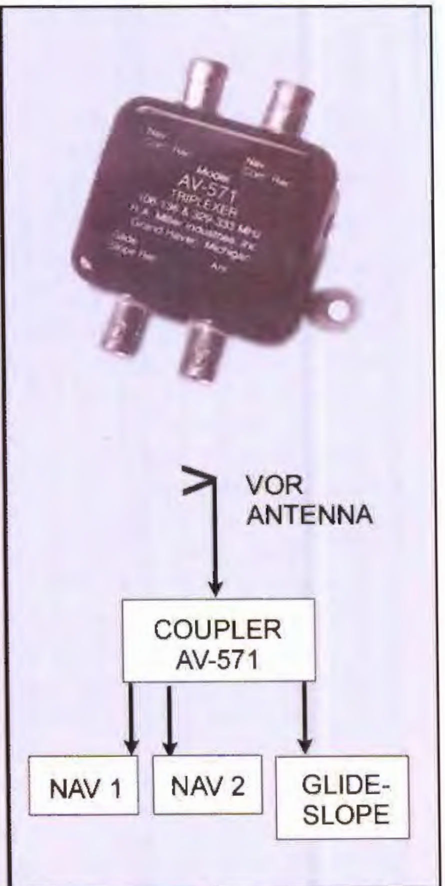
Antenna Couplers



The coupler splits the signal from a single antenna to feed two VOR navigation receivers. As in most couplers, it is only for receivers, which operate on very low-level signals. All couplers reduce the antenna signal by splitting, but there is ample signal strength remaining to do the job.



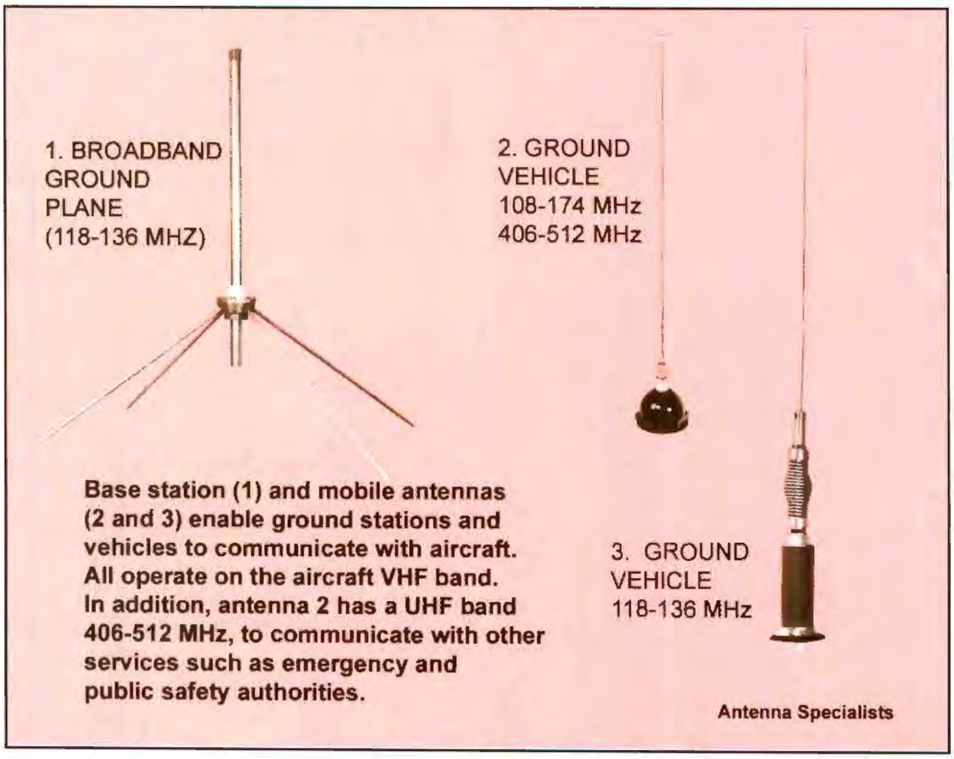
This coupler splits the signal from a VOR antenna for one nav receiver (VOR) and one glideslope receiver. Although the VOR antenna is designed for a frequency of 108 to 118 MHz, the coupler retrieves glideslope signals on 329 to 333 MHz. All couplers shown here are "passive," they need no power source.



RAMI (RA MILLER)

This coupler is found on more airplanes than any other type, especially light aircraft with basic IFR avionics. The coupler provides three outputs--Nav 1, 2 and glideslope---all from a single VOR antenna .

Base Station and Mobile Antennas



Base station (1) and mobile antennas (2 and 3) enable ground stations and vehicles to communicate with aircraft. All operate on the aircraft VHF band. In addition, antenna 2 has a UHF band 406-512 MHz, to communicate with other services such as emergency and public safety authorities.

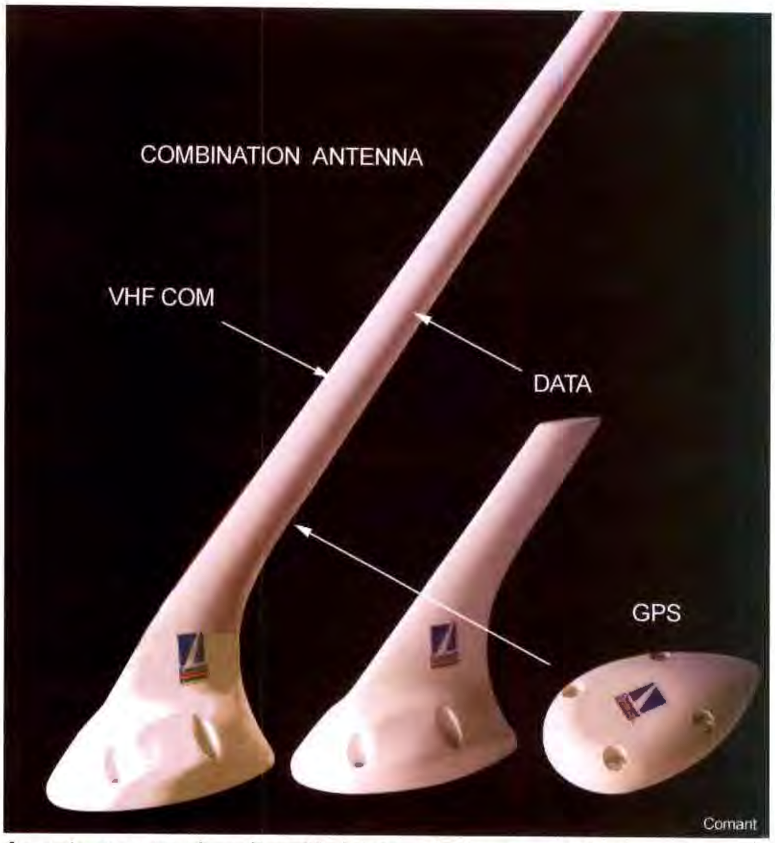
The favorite location for a GPS antenna is atop the cabin, several feet behind the windscreen. Place the antenna too far forward, near the front edge of the windscreen, and you may induce interference. As wind moves over the windows it generates static electricity that affects GPS reception. Also, keep away from propellers and the shadow of larger antennas.

On high-wing aircraft, mount the GPS antenna on top, keeping it near the leading edge of the wing (but away from the windshield). This reduces shadowing of the GPS signal when the airplane banks and climbs.

On large aircraft with a satellite communications antenna keep the GPS antenna at least four feet away. These two services are close in frequency and may produce interference to the GPS.

It's good practice to avoid bundling the GPS coaxial cable with cables from transmitting equipment. VHF com transmitters operate lower in frequency than GPS, but they produce harmonics that can reach up to the GPS band and cause trouble.

Some manufacturers offer a combined GPS-VHF antenna, which saves the installation of one antenna. The problem of interference between them is solved by a "notch" filter, which reduces the power of VHF harmonics before they reach the GPS antenna.



As antennas on aircraft multiply, manufacturers combine several into a single footprint. This example is ComDat; a VHF-com antenna at the left that also contains a GPS or data antenna. The combination not only saves space, it reduces installation time and effort. The antenna has two connectors in the base for attaching cables; a BNC-type for the com radio, and a TNC for GPS or data. The data radio handles such services as weather, messages and traffic information.

Review Questions
Chapter 27 Antenna Installation

27.1 What is the meaning of an arrow symbol on an antenna?

27.2 Why should antennas never be painted?

27.3 (A) What does VSWR mean? (B) What does it measure?

27.4 What is an "omnidirectional" antenna pattern?

27.5 What is antenna "impedance."

27.6 The matching device which connects a VOR antenna to its coaxial cable is called a ________.

27. 7 What is a poor location for an antenna?

27.8 What is a major difference between antennas for aircraft that cruise below 200 kt and aircraft that fly above that speed?

27.9 To avoid interfering with each other, antennas should be located at least ______inches apart.

27.10 Before mounting a new antenna, check the area inside the airplane for ____________, and _________.

27.11 What is the purpose of a doubler plate?

27.12 How many ohms of resistance indicate a good electrical bond between antenna base and airframe?

27.13 What is the function of an antenna coupler?

27.14 Do not locate a GPS antenna on the cabin roof immediately behind the windshield. Why?

Chapter 28

Panel Labels and Abbreviations

According to regulation, all controls and indicators on an airplane must be clearly labelled and visible to the pilot. Unmarked items can be handled several ways:

Send it out

There are specialty shops which offer panel-finishing services that produce durable and high quality labels.

Silk Screen

After the panel is painted, you can apply lettering by the silk screen process. This applies painted letters directly on the surface of the panel, much like a factory-made panel. You first prepare a drawing showing the position and lettering and send it to a shop which produces the silk screen. The panel is placed against the silk screen and paint applied with a roller. The paint is forced through holes in the screen and applied to the panel.

Engraving Machine

Many shops use an engraving machine to make labels. It works like a router, using a spinning bit to cut into the top surface of the label. When the bit reaches the second layer, it exposes white material. The router is controlled by a guide to form each character as a white letter or numeral. The completed label has an adhesive back that adheres to the panel.

Tape Labels

You type the label on the keyboard of a small machine which creates lettering on a plastic tape. There are many different color tapes and type sizes. The tapes run from 1/4-in to 1-inch wide.

Preprinted labels

These are sheets of labels with labels printed on them. An adhesive backing attaches them. Such labels are the least durable method.

Terms on Labels

The terms or words on labels may read differently from one manufacturer to the next. If you don't know what an abbreviation should be, the following chart shows recommended standards.

Panel Abbreviations

Abbreviations for instrument panels on airline and military aircraft are standardized. In General Aviation, corporate and many commercial aircraft, the choice is often left to the installer.

Industry organizations recommend the following abbreviations, which may be used directly on the panel, the faces of electromechanical instruments, in symbols of an electronic display (EFIS), switches, buttons, placards, legends, controls and in diagrams.

When using abbreviations, there are several basic rules:

Do not use periods (.) in abbreviations; for example: the word **DECREASE** becomes **DECR**

An abbreviation might look confusing, as in **ISCTN** (for **INTERSECTION).** In these instances, a hyphen is inserted: **I-SCTN**

A forward slash (/) means the term has a dual function. Example: **OFF/RESET** is **OFF/R**

There are a few exceptions. Some terms, such as **GLIDESLOPE** have always been abbreviated as **G/S.** Although it is one function, the forward slash is still used.

Over 1,300 terms appear in the following table. Besides serving as a guide to marking instrument panels, they can also decipher abbreviations on existing equipment and in diagrams.

A

ABEAM	ABM
ABNORMAL	ABNORM
ABOVE	ABV
ABOVE GROUND LEVEL	AGL
ABOVE MEAN SEA LEVEL	AMSL
ABSOLUTE	ABS
ACCELERATION	ACCEL
ACCEPT	ACPT
ACCUMULATOR	ACCU
ACKNOWLEDGE	ACK
ACQUIRE	ACQ
ACTIVATE	ACTV
ACTIVE	ACT
ACTUAL GROSS WEIGHT	AGW
ACTUAL TIME OF ARRIVAL	ATA
ACTUAL TIME OF DEPARTURE	ATD
ACTUAL TIME OVER	ATO
ADDRESS	ADRS
ADJUST	ADJ
ADVANCE	ADV
ADVISORY	ADVY
ADVISORY ROUTE	ADR
AERONAUTICAL INFORMATION SERVICE, PUBLICATION	AIS, AIP
AERONAUTICAL MOBILE SERVICE, FIXED SERVICE	AMS, AFS
AILERON	AIL
AIR CONDITIONING	AIRCOND
AIRCRAFT	ACFT
AIRCRAFT INTEGRATED DATA	AID
AIRCRAFT NOSE DOWN	ND
AIRCRAFT NOSE UP	NU
AIRCRAFT OPERATING MANUAL	AOM
AIR CYCLE MACHINE	ACM
AIR DATA	AD
AIR DRIVEN GENERATOR	ADG
AIR DRIVEN PUMP	ADP
AIRPORT	ARPT
AIRPORT BEACON	ABN
AIRPORT REFERENCE POINT	ARP
AIRPORT TRAFFIC ZONE	ATZ
AIRBORNE REPORT	AIREP
AIRSPEED	AS
AIRSPEED INDICATOR	ASI
AIR TO GROUND	AG
AIR TURBINE MOTOR	ATM
AIR ROUTE TRAFFIC CONTROL (CENTER)	ARTC(C)
AIR TRAFFIC CONTROL	ATC
AIR TRAFFIC SERVICES	ATS
AIRWAY	AWY
ALARM	ALM
ALERT, ALERTING	ALRT
ALERTING SYSTEM DISPLAY, ALERTING DISPLAY	ASD
ALPHABET, IC	ALPHA
ALIGNMENT	ALN
ALTERNATE	ALTN
ALTERNATING CURRENT	AC
ALTIMETER	ALTM
ALTITUDE	ALT
ALL SPEED AILERON	ASA
ALL UP WEIGHT	AUW
AMBIENT	AMB
AMMETER	AMM
AMPERE	AMP
AMPERE HOUR	AH
AMPLIFIER	AMPL
AMPLITUDE MODULATION	AM
ANALOG TO DIGITAL	A/D
ANALYZER	ANAL
ANGLE OF ATTACK	AOA
ANGULAR	ANG
ANNUNCIATOR	ANN
ANTENNA	ANT
ANTI ICE	AICE ANTI
SKID	ASKID
APPROACH	APPR
APPROACH CONTROL	APP
AREA CONTROL CENTER	ACC
AREA POSITIVE CONTROL	APC
AREA NAVIGATION	RNAV
ARINC COMMUNICATIONS, ADDRESSING AND REPORTING SYSTEM	ACARS
ARRIVAL, ING	ARR
ARTIFICIAL	ARTF
AS SOON AS POSSIBLE	ASAP
ASSEMBLY	ASSY
ASSIGN	ASSN
ASYMMETRIC	ASYM
ATTENDANT	ATTND
ATTENTION	ATTN
ATTITUDE	ATT
ATTITUDE DIRECTOR INDICATOR	ADI
ATTITUDE- HEADING REFERENCE	AHR
AUDIO	AUD
AUDIO SELECTOR PANEL	ASP
AUGMENT, ER, ATION	AUG
AUTOMATIC	AUTO
AUTOMATIC BRAKE	AB
AUTOMATIC DIRECTION FINDER	ADF
AUTOMATIC FLIGHT CONTROL	AFC
AUTOMATIC FLIGHT GUIDANCE	AFG
AUTOMATIC FLIGHT	AF
AUTOMATIC FREQUENCY CONTROL	AFC
AUTOMATIC GAIN CONTROL	AGC
AUTOMATIC LANDING	ALAND
AUTOMATIC LANDING	AL
AUTOMATIC RUDDER CONTROL	A-RUD
AUTOMATIC TEST EQUIPMENT	ATE
AUTOMATIC THRUST	AT
AUTOMATIC POWER RESERVE	APR
AUTOPILOT	AP
AUTOPILOT AND FLIGHT DIRECTOR	AFD
AUTOPILOT/FLIGHT DIRECTOR	AP/FD
AUTOSTABILIZER	ASTAB
AUTOTHROTTLE	AT
AUXILIARY	AUX
AUXILIARY DATA ACQUISITION UNIT	ADAU
AUXILIARY POWER UNIT	APU
AVAILABLE	AVAIL
AVERAGE	AV
AVIONICS	AVNCS
AZIMUTH	AZ

B

BACK BEAM	BBM
BACK COURSE	BCRS
BACK LOCALIZER	BLOC
BAROMETRIC SETTING	BARO
BATTERY	BAT
BATTERY UNIT	BU
BEACON	BCN
BEARING	BRG
BEARING DEVIATION INDICATOR	BDI
BEAT FREQUENCY OSCILLATOR	BFO
BELOW	BLW
BETWEEN	BTWN
BEVERAGE	BEV
BLUE	BLU
BOTTLE	BTL
BOTTOM OF CLIMB	BOC
BOTTOM OF DESCENT	BOD
BOUNDARY	BNDRY
BOUNDARY LAYER CONTROL	BLC
BRAKE	BRK
BRAKING ACTION	BA
BREAKOFF HEIGHT	BOH
BRIGHT, NESS	BRT
BROADCAST	BCST
BUILT IN TEST EQUIPMENT	BITE
BUS TIE BREAKER	BTB
BUS TIE RELAY	BTR
BUS TRANSFER CONTACTOR	BTC

C

CABIN	CAB
CALIBRATION	CAL
CALIBRATED AIR SPEED	CAS
CALL SIGN	CS
CANCEL	CNCL

Panel Abbreviations

CAPACITY	CPTY
CAPTAIN	CAPT
CAPTURE	CAP
CARBURETOR	CARB
CARD READER	CR
CARGO	CRG
CONTINUOUS WAVE	CW
CATEGORY	CAT
CATHODE RAY TUBE	CRT
CAUTION, ARY	CAUT
CAUTION AND WARNING	CAW
CEILING	CLNG
CEILING AND VIS UNRESTRICTED/OK	CAVU/CAVOK
CENTIGRADE	C
CENTIMETER	CM
CENTER	CTR
CENTER OF GRAVITY	CG
CENTER LINE	C/L
CENTRAL AIR DATA	CAD
CENTRAL PROCESSOR	CP
CHANGE	CHG
CHANNEL	CHAN
CHARGE, CHARGER	CHRG
CHECK	CK
CHECKED	CKD
CHECK LIST	CL
CHECK VALVE	CHKV
CHRONOMETER	CHR
CIRCLE	CRCL
CIRCUIT	CCT
CIRCUIT BREAKER	CB
CIRCUIT BREAKER MONITORING	CBM
CIRCULATE, CIRCULATION	CIRC
CLEAR	CLR
CLEAR AIR TURBULENCE	CAT
CLEARANCE	CLNC
CLEARED	CLRD
CLEARWAY	CWY
CLIMB	CLB

CLIMB SPEED MIN INITIAL	V3
CLIMB SPEED INITIAL	V4
CLOCK	CLK
CLOCKWISE	CW
CLOSE, CLOSED	CLS, CLSD
CLOUD	CLD
COCKPIT	CKPT
COCKPIT VOICE RECORDER	CVR
COLD	C
COLD AIR UNIT	CAU
COLLISION	COLL
COLLISION AVOIDANCE	CA
COMBINED SPEED INDICATOR	CSI
COMMAND	CMD
COMMANDER	CMDR
COMMUNICATION	COM
COMPANY	CO
COMPARATOR	CMPRTR
COMPARTMENT	COMPT
COMPASS	COMP
COMPLETE	CMPL
COMPRESSOR	CPRSR
COMPUTE	CMPT
COMPUTER	CMPTR
CONDITION	COND
CONFIGURATION	CONFIG
CONSTRAINT	CSTR
CONSTANT SPEED DRIVE	CSD
CONTACTOR	CNTOR
CONTINUE	CONT
CONTINUOUS REPETITIVE CHIME	CRC
CONTINUOUS WAVE	CW
CONTROL	CTL
CONTROL AREA	CTA
CONTROL DISPLAY	CD
CONTROL SYSTEM ELECTRONIC	CSE
CONTROL UNIT	CU

CONTROL WHEEL STEERING	CWS
CONTROL ZONE	CZ
COOLER, ING	COOL
COPILOT	CP
CORRECT	CORR
COST INDEX	CI
COUNTER CLOCKWISE	CCW
COUPLE	CPL
COUPLER	CPLR
COURSE	CRS
COURSE DEVIATION INDICATOR	CDI
COWLING	COWL
CREW MEMBER	CM
CRITICALENGINE FAIL SPEED	V1
CRITICAL POINT	CP
CROSSCREW QUALIFICATION	CCQ
CROSS BAR	XBAR
CROSS FEED	XFD
CROSS LINE	XLN
CROSS TRACK DEVIATION	XTK
CROSS TRACK ERROR	XTKE
CROSS VALVE	XVLV
CROSS WIND	XWND
CRUISE	CRZ
CRUISING SPEED DESIGN	VC
CYLINDER	CYL
D	
DAMPER	DMPR
DANGER, -OUS	DNGR
DANGER AREA	DA
DATA ENTR, DISPLAY PANEL	DEDP
DATA LINK	DL
DATA MANAGEMENT	DM
DATE	DAT
DEAD RECKONING	DR
DECELERATE, ION	DECEL
DECIBEL	DB
DECISION ALTITUDE	DA
DECISION HEIGHT	DH
DECISION SPEED	V1
DECK	DK
DECLINATION	DEC
DECREASE	DECR
DEFINITION	DEF
DEFLECTION	DEFL
DEGREE	DEG
DEICE	DICE
DELAY	DLA
DELAY MESSAGE	DEL
DELAYED FLAP APPROACH	DFA
DELETE	DEL
DEPARTURE	DEP
DEPARTURE MESSAGE	DEP
DEPRESSURIZE, ATION	DPR
DESCEND, DESCENT	DES
DESIGN EYE POSITION	DEP
DESIGNATOR	DSIG
DESIRED TRACK	DTK
DESTINATION	DEST
DETECTED, TOR, TION	DET
DEVIATION	DEV
DIFFERENCE, TIAL	DIFF
DIFFERENTIAL PRESSURE	dP
DIGITAL AIDS RECORDER	DAR
DIGITAL AIR DATA (Equipment)	DAD
DIGITAL DISTANCE AND RADIO MAGNETIC INDICATOR	DDRMI
DIGITAL FLIGHT DATA ACQUISITION UNIT	DFDAU
DIGITAL FLIGHT DATA RECORDER	DFDR
DIGITAL TO ANALOG	D/A
DILUTER, ION	DIL
DIRECT, ION, DIRECT TO	DIR
DIRECT CURRENT	DC
DIRECTIONAL GYRO	DG
DIRECTION FINDER	DF
DIRECT LIFT CONTROL	DLC
DIRECT OPERATING COST	DOC
DISARMED	DISRMD
DISCHARGE	DISCH
DISCONNECT	DISC

Kroy

There are machines for printing labels with adhesive backing.

Panel Abbreviations

DISENGAGED	DISENG
DISPLAY	DSPL
DISPLAY UNIT	DU
DISTANCE	DIST
DISTANCE MEASURING EQUIPMENT	DME
DISTANCE TO GO	DTG
DIVERSION	DVRSN
DIVERT	DVRT
DOPPLER	DOPP
DOUBLE SIDE BAND	DSB
DOWN	DN
DRIFT	DFT
DRIFT ANGLE	DA
DRIFT DOWN	DD
DRIVE	DRV
DRY OPERATING WEIGHT	DOW
E	
EARTH ACCELERATION	g
EAST	E
ECONOMIC, MY	ECON
EFFECTIVE	EFF
ELAPSED TIME	ET
ELECTRIC, AL, ITY	ELEC
ELECTROMAGNETIC INTERFERENCE	EMI
ELECTRONIC	ELEX
ELECTRONIC ADI	EADI
ELECTRONIC CENTRALIZED AIRCRAFT MONITOR	ECAM
ELECTRONIC COOLING SYSTEM	ECS
ELECTRONIC ENGINE CONTROL	EEC
ELECTRONIC FUEL CONTROL	EFC
ELECTRONIC FLIGHT INSTRUMENT	EFI
ELECTRONIC HSI	EHSI
EXPAND, SION	EXP
EXPECTED APPROACH TIME	EAT
EXPEDITE	XPED
EXTEND, -ED	EXTD
EXTENDED FUNCTION	XFCN
EXTERNAL, EXTERIOR	EXT
EXTERNAL POWER CONTACTOR	EPC
EXTINGUISH, -ER	EXTING
EXTRA FUNCTION	XFCN
EXTRACT	EXTR
EXTRACT REFERENCE POSITION	ERP
F	
FAHRENHEIT	F
FAILURE, FAILED	FAIL
FAN SPEED	N1
FAST/SLOW	F/S
FAULT ISOLATION MONITOR	FIM
FAULT REPORTING MANUAL	FRM
FEEL SIMULATION UNIT	FSU
FEET, FOOT	FT
FEET PER MINUTE	FPM
FIELD ELEVATION PRESSURE	QFE
FIGURE	FIG
FILAMENT	FIL
FILTER	FLTR
FINAL T 0 SAFETY SPEED	VFTO
FINAL APPROACH FIX	FAF
FIRST OFFICER	FO
FINAL APPROACH	FNA
FLAP	FLP
FLAP EXTENDED SPEED MAX	VFE
FLAP OPERATING SPEED MAX	VFO
FLARE	FLR
FLEXIBLE	FLEX
FLIGHT AUGMENTATION COMPUTER	FAC
FLIGHT	FLT
FLIGHT CONTROL	FC
FLIGHT CREW OPERATING MANUAL	FCOM
FLIGHT DATA ACQUISITION UNIT	FDAU
FLIGHT DATA ENTRY PANEL	FDEP
FLIGHT DATA RECORDER	FDR
FLIGHT DATA STORAGE UNIT	FDSU
FLIGHT DECK	FDK
FLIGHT DATA ENTRY PANEL	FDEP
FLIGHT DATA RECORDER	FDR
FLIGHT DATA STORAGE UNIT	FDSU
FLIGHT DECK	F-DK
FLIGHT DIRECTOR	FD
FLIGHT ENGINEER	FE
FLIGHT GUIDANCE	FG
FLIGHT INFORMATION CENTER	FIC
FLIGHT INFORMATION REGION	FIR
FLIGHT INFORMATION REGION BOUNDARY	FIRB
FLIGHT INFORMATION SERVICE	FIS
FLIGHT LEVEL	FL
FLIGHT LEVEL CHANGE	FL CH
FLIGHT MANAGEMENT SYSTEM	FM8
FLIGHT MODE ANNUNCIATOR	FMA
FLIGHT NAVIGATION	FN
FLIGHT PATH ANGLE	FPA
FLIGHT PATH TARGET	FPT
FLIGHT PATH VECTOR	FPV
FLIGHT PLAN	FPLN
FLIGHT WARNING	FW
FLIGHT (WEATHER) FORECAST	FIFOR
FLOW	FLO
FLUORESCENT	FLUOR
FOOT, FEET	FT
FORECAST	FCST
FOREIGN OBJECT DAMAGE	FOD
FORWARD	FWD
FREEZE	FRZ
FREQUENCY	FREQ
FREQUENCY MODULATION	FM
FROM	FR
FRONT	FRT
FUEL CONTROL UNIT	FCU
FUEL FLOW	FF
FUEL ON BOARD	FOB
FUEL OVER DESTINATION	FOD
FUEL QUANTITY	FQ
FUEL USED	FU
FUNCTION	FCTN
FUSELAGE	FUS
G	
GALLEY	GLY
GALLON	GAL
GENERAL	ENL
GENERATOR	GEN
GENERATOR CONTROL UNIT	GCU
GENERATOR LINE CONTACTOR	GLC
GENERATOR LINE RELAY	GLR
GEOGRAPHICAL REFERENCE POINT	GRP
GO AROUND	GA
GLARESHIELD	GSHLD
GLIDE SLOPE	G/S
GLIDE PATH	GP
GLOBAL POSITIONING SYSTEM	GPS
GRAM	G
GRAVITY	g
GREEN	GRN
GREENWICH MEAN TIME	GMT
GROSS WEIGHT	GW
GROUND	GND
GROUND CONTROLLED APPROACH	GCA
GROUND MOVEMENT CONTROL	GMC
GROUND MOVEMENT RADAR	GMR
GROUND POWER UNIT	GPU
GROUND PROXIMITY WARNING	GPW
GROUND REFERENCE POINT	GRP
GROUND ROLL	GR
GROUND SPEED	GS
GROUND TO AIR	GA
GUST SPEED DESIGN MAX	VB
GYRO	G
H	
HANDLE	HNDL
HEAD	HD
HEADING	HDG
HEADING AND ATTITUDE	HA
HEADING SELECT	HDGS
HEAD UP DISPLAY	HUD
HEAD WIND	HWND
HEAT	HT
HEATER	HTR
HEIGHT	H
HELICOPTER	HEL
HERTZ	HZ
HIGH	HI
HIGH FREQUENCY	HF
HIGH LEVEL	HL
HIGH PRESSURE	HP
HIGH SPEED	HSPD
HOLD, ING, HOLDING PATTERN	HLD
HORIZONTAL NAVIGATION	HNAV
HORIZONTAL SITUATION INDICATOR	HSI
HOT	H
HOUR	HR
HYDRAULIC	HYD
I	
ICING	ICE
IDENTIFICATION BEACON	IBN
IDENTIFY, IER, ICATION	ID
IGNITION	IGN
IMMEDIATE	IMM
INBOARD	INBD
INBOUND	INB
INCHES	IN(S)
INCLUDE, SIVE	INC
INCREASE, ING	INCR
INDEX	INDX
INDICATED AIRSPEED	IAS
INDICATOR, ION, ED	IND
INERTIAL	I
INERTIAL NAVIGATION	IN
INERTIAL NAVIGATION SYSTEM	INS
INERTIAL REFERENCE	IR
INERTIAL SENSOR	IS
IN-FLIGHT ENTERTAINMENT	IFE
INFORMATION	INFO
INHIBITION	INHIB
INITIAL, ATION, IZATION	INIT
INITIAL APPROACH	INA
INITIAL APPROACH FIX	IAF
INITIAL POINT	IP
INJECTION	INJ
INLET (INTAKE) GUIDE VANES	IGV
INNER	INR
INNER MARKER	IM
INOPERATIVE	INOP
INPUT/OUTPUT	I/0
INSTRUMENT	INST
INSTRUMENT FLIGHT RULES	IFR
INSTRUMENT LANDING SYSTEM	ILS
INSTRUMENT METEOROLOGICAL CONDITIONS	IMC
INTAKE	INTK
INTEGRATED DRIVE GENERATOR	IDG
INTERCEPT	INTCP
INTERCEPT POINT	IPT
INTERCOM, INTERCOMMUNICATION	I/C
INTERLOCK	INTLK
INTERMEDIATE FIX	IF
INTERMEDIATE PRESSURE	IPR
INTERNATIONAL	INTL
INTERNATIONAL STANDARD ATMOSPHERE	ISA
INTERPHONE	INPH
INTERRUPT, ED, ION	INTRP
INTERSECTION	ISCTN
INTER SYSTEM BUS	ISB
INVERTER	INV
ISOLATE, ED, ION	ISOL
J	
JAMMED, -ING	JAM
JET PIPE TEMPERATURE	PT
JUNCTION	JCT
K	
KEYBOARD	KYBD
KILO	K

Panel Abbreviations

KRUGER	KRUG
KNOTS)	KT(S)
L	
LANDING	LDG
LANDING DIRECTION INDICATION	LDI
LANDING GEAR	LG
LANDING GEAR EXTENDED SPEED MAX	VLE
LANDING GEAR OPERATING SPEED MAX	VLO
LANDING REFERENCE SPEED	VREF
LANDING WEIGHT	LW
LASER	LSR
LATERAL, LATITUDE	LAT
LATERAL NAVIGATION	LNAV
LATERAL REVISE	LREV
LATCH	LTCH
LATITUDE	LAT
LATITUDE/LONGITUDE	L/L
LAVATORY	LAV
LEADING EDGE	LE
LEAST SIGNIFICANT BIT	LSB
LEFT	L
LEFT HAND (SIDE)	LH
LEFT LINE SELECT (KEY)	LLS
LEFT WING DOWN	LWD
LENGTH	L
LEVEL	LVL
LEVEL CHANGE	CHG
LEVER	LVR
LIGHT, LIGHTS	LT
LIGHT EMITTING DIODE	LED
LIMIT	LIM
LIMITER	LMTR
LINEAR	LIN
LINE REPLACEABLE UNIT	LRU
LINE SELECT KEY	LSK
LIQUID OXYGEN	LOX
LITER	L
LOAD	LD
LOAD CLASSIFICATION NUMBER	LCN
LOAD RELIEF SYSTEM	LRS
LOAD SHEDDING RELAY	LSR
LOCAL	LCL
LOCAL MEAN TIME	LMT
LOCALIZER	LOC
LOCALIZER INERTIAL SMOOTHING	LIS
LOCALIZER TYPE DIRECTIONAL AID	LDA
LOCATION	LCTN
LOCATOR	LCTR
LOCKED	LKD
LONG RANGE CRUISE	LRC
LONG RANGE NAVIGATION	LORAN
LONGITUDE, -INAL	LONG
LOW	LO
LOWER	LWR
LOWER SIDE BAND	LSB
LOW FREQUENCY	LF
LOW LEVEL	LL
LOW PRESSURE	LP
LOW SPEED	LSPD
LOW SPEED AILERON	LSA
M	
MACH	M
MACH/AIRSPEED INDICATOR	M/ASI
MAGNETIC	MAG
MAGNETIC INDICATOR	MI
MAIN LANDING GEAR	MLG
MAINTAIN, MAINTENANCE	MAINT
MAINTENANCE CONTROL AND DISPLAY PANEL	MCDP
MAINTENANCE TEST PANEL	MTP
MALFUNCTION	MALF
MANDATORY OCCURRENCE REPORT	MOR
MANIFOLD	MANF
MANEUVER SPEED DESIGN	VA
MANEUVER SPEED RECOMMENDED	VMAN
MANUAL	MAN
MARKER	MKR
MARKER BEACON	MB
MASTER	MSTR
MASTER WARNING	MW
MAXIMUM	MAX
MAXIMUM CONTINUOUS THRUST	MCT
MAXIMUM CRUISE	MCR
MAXIMUM LANDING WEIGHT	MLW
MAXIMUM RAMP WEIGHT	MRW
MAXIMUM OPERATING SPEED MACH	MMO
MAXIMUM OPERATING SPEED AIRSPEED	VMO
MAXIMUM TAXI WEIGHT	MTXW
MAXIMUM TAKEOFF GROSS WEIGHT	MTOGW
MAXIMUM TAKEOFF WEIGHT	MTOW
MAXIMUM ZERO FUEL WEIGHT	MZFW
MEAN AERODYNAMIC CHORD	MAC
MEAN SEA LEVEL	MSL
MEAN TIME BETWEEN FAILURE	MTBF
MECHANIC	MECH
MEDIUM	MED
MEDIUM FREQUENCY	MF
MEGA	M
MEMORY/MEMORANDUM	MEM
MERCURY	Hg
MESSAGE	MSG
METER	M
METERING FIX	MF
METEOROLOGICAL	MET
MICROPHONE	MIC
MICROWAVE LANDING SYSTEM	MLS
MIDDLE, MIDSHIP	MID
MIDDLE MARKER	MM
MILE	MI
MILES PER HOUR	MPH
MILLIBAR(S)	Mb
MINIMUM	MIN
MINIMUM APPROACH BREAKOFF HEIGHT	MABH
MINIMUM CONTROL SPEED	VMC
MINIMUM DECISION/DESCENT ALTITUDE	MDA
MINIMUM EN ROUTE ALTITUDE	MEA
MINIMUM EQUIPMENT LIST	MEL
MINIMUM OPERATING SPEED	VMIN
MINIMUM REQUIREMENT LIST	MRL
MINIMUM SAFE ALTITUDE	MSA
MINIMUM SECTOR FUEL	MSF
MINIMUM ZERO FUEL WEIGHT	MZFW
MINUTE	MN
MISCELLANEOUS	MISC
MISSED	MSD
MISSED APPROACH POINT	MAP
MISSED APPROACH PROCEDURE	MA PROC
MODERATE	MOD
MODE CONTROL	MC
MODE SELECT PANEL	MSP
MODIFY, MODIFICATION	MOD
MODULAR CONCEPT UNIT	MCU
MONITOR, ED	MON
MOTOR	MOT
MOUNTING	MTG
MULTIFUNCTION DISPLAY	MFD
MULTIPLEX	MUX
N	
NACELLE	NAC
NAUTICAL MILES	NM
NAUTICAL MILES PER HOUR (KNOTS)	KTS
NAVIGATION/COMMUNICATION	NAVCOM
NAVIGATION, NAVIGATOR	NAV
NAVIGATION AID	NAVAID
NAVIGATION DISPLAY	ND
NAVIGATION REFERENCE POINT	NRP
NEGATIVE	NEG
NEXT	NXT
NEXT PAGE	NP
NEUTRAL	NEUT
NOISE ABATE, ABATEMENT	NA
NON DIRECTIONAL BEACON	NDB
NON RETURN VALVE	NRV
NORMAL	NORM
NORTH	N
NOSE LAUDING GEAR	NLG
NOSE WHEEL	NW
NOTICE TO AIRMEN	NOTAM
NUMBER	#
O	
OBSERVED, -ATION	OBSV
OBSERVER	OBSR
OBSTACLE, OBSTRUCTION	OBST
OBSTACLE CLEARANCE LIMIT	OCL
OFF/RESET	OFF/R
OFFSET	OFST
OMEGA	O
OMEGA NAVIGATION	ON
OMNI BEARING SELECTOR	OBS
ON BOARD BALANCE SYSTEM	OBBS
ON BOARD WEIGHING SYSTEM	OBWS
ON BOARD WEIGHT AND BALANCE SYSTEM	OBWBS
OPEN	O
OPERATIONAL	OP
OPERATIVE, ING	OPER
OPERATION	OPS
OPERATION, ING MANUAL	OM
OPPOSITE	OPP
OPTIMUM	OPT
OUTBOARD	OUTBD
OUTBOUND	OUTB
OUTER	OUTR
OUTER MARKER	OM
OUTLET	OUTL
OUTPUT/INPUT	O/I
OUTSIDE AIR TEMPERATURE	OAT
OVERBOARD	OVBD
OVERFLOW	OVFL
OVERHEAD	OVHD
OVERHEAT	OVHT
OVERLOAD	OVLD
OVER PRESSURE	OVPR
OVERRIDE	OVRD
OVERRUN	OVRN
OVERSPEED	OVSPD
OXYGEN	OXY
P	
PACK	PK
PAGE	PG
PANEL	PNL
PARALLEL TRACK	PTK
PARAVISUAL DIRECTOR	PVD
PARK	PK
PASSENGERS	PAX
PASSENGER ADDRESS	PA
PASSENGER ENTERTAINMENT SYSTEM	PES
PATTERN	PAT
PEDAL	PEDL
PEDESTAL	PED
PER CENT	%
PERFORMANCE	PERF
PERFORMANCE MANAGEMENT	PM
PILOT	PLT
PILOT FLYING	PF
PILOT IN COMMAND	PIC
PILOT NOT FLYING	PNF
PITCH	PTCH
PITCH AUGMENTATION COMPUTER	PAC
PLAN, (FLIGHT PLAN)	PLN
PLAN POSITION INDICATOR	PPI
PLANNED LANDING WEIGHT	PLW
PLATFORM	PLATF
PNEUMATIC	PNEU
POINT	PT
POINT OF NO RETURN	PNR
POSITION	POS
POSITIVE	POS
POSSIBLE	PSBL
POTABLE WATER	POTW
POUND	LB
POUNDS PER SQUARE INCH	PSI
POWER	PWR
POWER CONTROL UNIT	PCU
POWER TRANSFER UNIT	PTU
PRECISION APPROACH PATH INDICATOR	PAPI
PRECISION APPROACH RADAR	PAR
PREDICTED, TION	PRED
PREDICTED WIND DATA	PWD
PREFERRED	PREFD

Panel Abbreviations

PREFLIGHT	PREFLT
PRESENT	PRES
PRESENT POSITION	POS
PRESSURE	PRESS
PRESSURIZATION	PRESN
PREVIOUS	PREV
PRIMARY	PRI
PRIMARY FLIGHT DISPLAY	PFD
PRINTER	PRTR
PROCEDURE	PROC
PROCEDURE TURN	PROCT
PROFILE	PROF
PROGRAM	PRGM
PROGRESS	PROG
PROPELLOR	PROP
PROTECTION	PROT
PROXIMITY	PROX
PURSER	PURS
PUSH BUTTON	PB
PUSH (PRESS) TO ARM	PTA
PUSH (PRESS) TO CANCEL	PTC
PUSH (PRESS) TO RESET	PTR
PUSH (PRESS) TO SET	PTS
PUSH (PRESS) TO TALK/TRANSMIT	PTT
PUSH (PRESS) TO TEST	PTT
PUSH (PRESS) TO INHIBIT	PTI
Q	
QUADRANT	QUAD
QUANTITY	QTY
QUART	QT
QUICK ACCESS RECORDER	QAR
R	
RADIO	RAD
RADAR	RDR
RADAR HEIGHT/RADIO HEIGHT	RHT
RADIAL	R
RADIAL/DISTANCE	R/D
RADIO ALTIMETER	RA
RADIO/INERTIAL	R/I
RADIO DISTANCE MAGNETIC INDICATOR	RDMI
RADIO MAGNETIC INDICATOR	RMI
RADIO MANAGEMENT	RM
RADIO NAVIGATION INDICATOR	RNI
RADIO RANGE	RNG
RADIO TELETYPEWRITER	RTT
RADIO TELEPHONE	RT
RAM AIR TEMPERATURE/TURBINE	RAT
RANDOM (AREA) NAVIGATION	RNAV
RANGE	RNG
RATE OF CLIMB	ROC
RATE OF DESCENT	ROD
READY	RDY
REAR (PART)	AFT
RECALL	RCL
RECEIVE	RCV
RECEIVER	RCVR
RECIRCULATION	RECIRC
RECLEAR, ED	RCLR
RECORDER	RCDR
RECTIFIER	RECT
REDUCTION	REDN
REDUNDANT, -ANCY	REDUND
REFERENCE	REF
REFERENCE EYE POSITION	REP
REFERENCE SPEED; THRESHOLD)	VREF
REFRIGERATION	FRIG
REFUEL	RFL
REGULATOR	REG
REGULATED TAKEOFF WEIGHT	RTOW
REJECTED TAKEOFF	RTO
RELAY	RLY
RELEASE	REL
REMAIN	RMN
REMOTE	REM
REMOTE CONTROLLED CIRCUIT BREAKER	RCCB
REPEATING	RPTG
REPELLENT	RPLNT
REPETITIVE CHIME	RC
REPETITIVE STROKE	RS
REPORT	REP
REPORTING POINT	RPT
REQUEST	REQ
REQUIRED	REQD
REQUIRED TIME OF ARRIVAL	RTA
RESERVE, ATION	RSV
RESERVOIR	RSVR
RESET	RST
RESPONDER BEACON	RSP
RESTRICTED, TION	REST
RETARD	RETD
RETRACT, ED, ABLE	RETR
RETURN	RET
REVERSE, REVISION, REVISE	REV
REVERSE CURRENT PROTECTION	RCP
REVERSER	RVSR
REVOLUTIONs PER MINUTE	RPM
RIGHT	R
RIGHT HAND (SIDE)	RH
RIGHT LINE SELECT (KEY)	RLS
RIGHT WING DOWN	RWD
ROTARY	RTRY
ROTATION SPEED	VR
ROTOR	RTR
ROUGH AIR SPEED	VRA
ROUTE	RTE
ROUTE SURVEILLANCE RADAR	RSR
RUDDER	RUD
RUNWAY	RWY
RUNWAY HEADING	QFU
RUNWAY VISUAL RANGE	RVR
S	
SATELLITE	SAT
SCREEN	SCRN
SEA LEVEL	SL
SEA LEVEL PRESSURE	QNH
SECONDS	SEC
SECOND, SECONDARY	2ND
SECONDARY SURVEILLANCE RADAR	SSR
SECTION	SECT
SECTOR	SCTR
SEGMENT	SEG
SELECT, ED, ION, OR	SEL
SELECTIVE CALL	SELCAL
SENSITIVITY	SENS
SEPARATE, TION	SEP
SEQUENCE, TIAL	SEQ
SERVICE	SERV
SERVICING	SVNG
SERVICEABLE	SVBL
SERVO ALTIMETER	SVALT
SERVO MOTOR	SVMOT
SHAKER	SHKR
SHED, -DING	SHED
SHIELD, ING	SHLD
SHOP REPLACEABLE UNIT	SRU
SHORT	SHT
SHORT TAKE OFF AND LANDING	STOL
SHORT TAKE OFF AND VERTICAL LANDING	STOVL
SHUTTER	SHTR
SIGNAL	SIG
SIMULATE, -TOR	SIM
SIMULTANEOUS	SIMUL
SINGLE SIDE BAND	SSB
SINGLE CHIME	SC
SINGLE STROKE CHIME	SSC
SITUATION	SIT
SKIP	SKP
SLAT	SLT
SLOW	S
SMOKE	SMK
SMOKING	SMKG
SOUTH	S
SPACE	SP
SPEAKER	SPKR
SPECIAL	SPCL
SPECIFIC, ATION	SPEC
SPECIFIC FUEL CONSUMPTION	SFC
SPEED	SPD
SPEED BRAKE	SPBK
SPEED CLIMB	SPD CLB
SPEED COMMAND	SC
SPEED DESCENT	SPD DES
SPEED REFERENCE SYSTEM	SRS
SPOILER	SPLR
SQUELCH	SQ
SQUIB	SQB
STABILITY, IZER, IZATION	STAB
STALL SPEED	VS
STANDARD	STD
STANDARD INSTRUMENT DEPARTURE	SID
STANDARD OPERATING PROCEDURE	SOP
STEADY	STDY
STEERING	STRG
STEP CLIMB	STEP CLB
STEP DESCENT	STEP DES
STOPWAY	SWY
STRAIGHT IN APPROACH	STA
SUBSTITUTE	SUB
SUPPLY	SPLY
SURFACE	SURF
SURVEILLANCE RADAR	SR
SWITCH	SW
SYMBOL GENERATOR UNIT	SGU
SYMMETRICAL	SYM
SYNCHRONIZE, ATION	SYNC
SYSTEM	SYS
SYSTEM DATA ANALOG CONVERTER	SDAC
SYSTEM DISPLAY	SD
T	
TACHOMETER	TACH
TACTICAL	TAC
TACTICAL AIR NAVIGATION	ACAN
TAILPLANE INCIDENCE	TPI
TAILWIND	TWND
TAKEOFF	TO
TAKEOFF DISTANCE	TOD
TAKEOFF FINAL SAFETY SPEED	VFTO
TAKEOFF FUEL	TOF
TAKEOFF/GO AROUND	TO/GA
TAKEOFF GROSS WEIGHT	TOGW
TAKE OFF SAFETY SPEED	V2
TAKEOFF WIGHT	TOW
TANK	TNK
TARGET	TRGT
TAXI WAY	TWY
TELEPHONE	TEL
TELETYPEWRITER	TT
TEMPERATURE	TEMP
TERMINAL	TML
TERMINAL AREA SURVEILLANCE RADAR	TAR
TERMINAL (MOVEMENT) AREA	TMA
TERMINAL FORECAST	TAF
TERRAIN	TERR
TEST	TST
THRESHOLD SPEED TARGET	VAT
THROTTLE	THROT
THRUST	THR
THRUST CONTROL	TC
THRUST MANAGEMENT	TM
THRUST RATING	TR
THRUST REVERSER	HR REV
TIME	THE
TIMER	TMR
TIME TO GO	TTG
TO BE DETERMINED	TBD
TOP OF CLIMB	TOC
TOP OF DESCENT	TOD
TOTAL AIR TEMPERATURE	TAT
TOUCH AND GO LANDING	TGL
TOUCHDOWN	TDN
TOUCHDOWN POINT	TDP
TOUCHDOWN ZONE	TDZ
TOWER	TWR
TRACK	TRK
TRACK ANGLE ERROR	TKE
TRACK MADE GOOD	TMG
TRAFFIC	TRFC
TRAILING EDGE	TE
TRANSCEIVER	XCVR
TRANSFER	XFER
TRANSFEROFCONTROL MESSAGE	TFR
TRANSFORMER	XFMR
TRANSFORMER RECTIFIER	TR
TRANSITION	TRANS

Panel Abbreviations

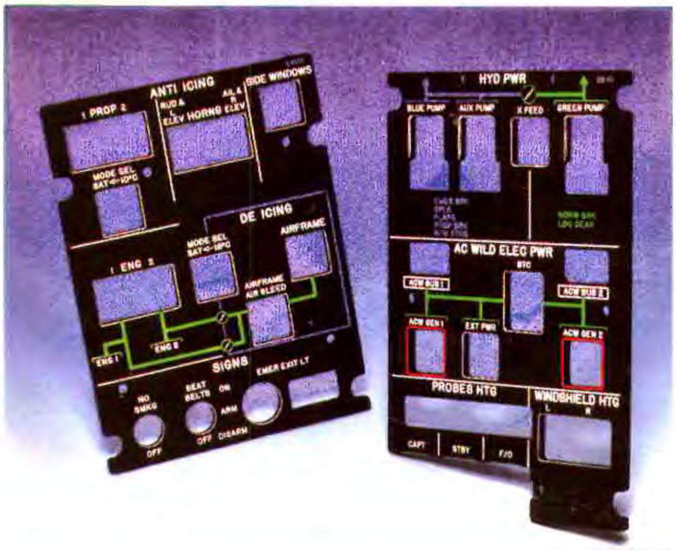
TRANSITION LEVEL	QNE
TRANSMITTER	XMTR
TRANSMITTER/RECEIVER	T/R
TRANSPONDER	XPDR
TRAVEL	TRVL
TROPOPAUSE	TROPO
TRUE	TRU
TRUE AIRSPEED	TAS
TRUE TRACK	TTK
TURBINE	TUR
TURBINE GAS TEMPERATURE	TGT
TURBINE INLET TEMPERATURE	TIT
TURBINE VIBRATION INDICATOR	TVI
TURBULENCE	TURB
TURN AND SLIP	T/S
TURN POINT	TPT
TURN RADIUS	TRAD

U

ULTRAHIGH FREQUENCY	UHF
ULTRAVIOLET	UV
UNABLE	UNABL
UNAVAILABLE	UNAVAIL
UNCOUPLED, ING	UNCPL
UNDERFLOOR	UFLOOR
UNLOCK, ED	UNLK
UNSERVICEABLE	U/S
UPPER	UPR
UPPER AIRWAY	UWY
UPPER AREA CONTROL CENTER	UAC
UPPER CONTROL AREA	UTA
UPPER SIDEBAND	USB
UTILITY	UTIL
UPPER FLIGHT INFORMATION REGION	UIR

V

VACUUM	VAC
VALVE	VLV
VARIATION, VARIABLE	VAR
VECTOR	VECT
VELOCITY	VEL
VENTILATION	VENT
VERIFY	VRFY
VERTICAL	VERT
VERTICAL BEARING	VBRG
VERTICAL DEVIATION	VDEV
VERTICAL GYRO	VG
VERTICAL NAVIGATION	VNAV
VERTICAL PROFILE	VPROF
VERTICAL REFERENCE UNIT	VRU
VERTICAL REVISE	VREV
VERTICAL SITUATION DISPLAY	VSD
VERTICAL/SHORT TAKEOFF AND LANDING	V/STOL
VERTICAL SPEED	VS
VERTICAL SPEED INDICATOR	VSI
VERTICAL TAKEOFF AND LANDING	VTOL
VERTICAL TRACK	VTK
VERTICAL TRACK ERROR	VTE
VERY HIGH FREQUENCY	VHF
VERY HIGH FREQUENCY DF STATION	VDF
VERY LOW FREQUENCY	VLF
VHF NAVIGATION	VHF/NAV
VHF OMNIDIRECTIONAL RANGE	VOR
VHF OMNITEST	VOT
VIBRATION	VIB
VISIBILITY	VIS
VISUAL APPROACH SLOPE INDICATOR	VASI
VISUAL FLIGHT RULES	VFR
VISUAL METEOROLOGICAL CONDITIONS	VMC
VLF/OMEGA	VLF/O
VOLT	V
VOLUME	VOL
VOR/DME	V/D
VOR/ILS	V/I
VOR/LOC	V/L
VOR TACTICAL AIR NAVIGATION	VORTAC



Paramount

Panels may be fabricated, finished and labelled by an outside shop specializing in this work.

W

WARNING	WARN
WARNING AND SYSTEM CONTROL PANEL	WSCP
WARNING DISPLAY	WD
WARNING LIGHTS	WL
WARNING SYSTEM	WS
WATER	WTR
WATT	W
WAYPOINT	WPT
WEATHER	WX
WEATHER RADAR	WXR
WEIGHT	WT
WEIGHT, ALTITUDE, TEMPERATURE	WAT
WEST	W
WHEEL	WHL
WHEEL WELL	WW
WIND DIRECTION	WDIR
WIND SPEED	WSPD
WIND VELOCITY	W/V
WINDSHIELD	WSHLD
WINDSHIELD GUIDANCE	WG
WING AND TAIL	WT
WINGTIP BRAKE	WTB

Y

YAW DAMPER	YD
YELLOW	YEL

Z

ZERO FUEL WEIGHT	ZFW
ZONE	ZN

Chapter 29

Test and Troubleshooting

The first step in troubleshooting an avionics problem is when the pilot describes the complaint to the technician, or fills out a squawk sheet. The quality of these reports often means the difference between a quick fix or wasted hours looking for trouble.

The typical pilot squawk is often brief, such as "My number 1 com doesn't work." This gives few clues and is only the starting point to ask questions to narrow the problem. The pilot knows much more than he thinks---if the technician asks well-placed questions.

Here are suggestions to make the diagnosis go faster. Frame your questions to learn the conditions surrounding the failure (we'll use the com as an example):

Does the problem affect *both* transmit and receive?

Does the problem happen in all directions?

Does it occur over both high and low terrain?

If there are two navcoms, are both transmitters affected?

Is communicating distance affected by the weather?

Is the problem worse during taxi and takeoff, then improves while cruising?

Have you tried a different microphone?

When was the most recent repair to any avionics equipment?

Answers to specific questions like these can narrow down the faulty area.

Technical Terms

Be certain you and the pilot are talking about the same thing. For example, one pilot said "My speaker doesn't work,"---but pointed to his *microphone*. To him, it was a "speaker" because he spoke into it.

Avoid talking "avionics tech" because pilots

TCAS Ramp Testing

Tests to verify and certify a TCAS (Traffic Alert and Collision Avoidance System) can be done outside the airplane. The ramp tester, an Aeroflex TCAS-201, communicates with the airplane via radio signals and simulates different collision conditions. Without connecting directly into airplane systems it measures signal power, frequency, interrogations and replies. The tester is programmable to perform ten different collision scenarios.

Selective Call Test

Selective calling systems aboard aircraft are checked remotely by this ramp tester, the Avtech CTS-700. It sends and receives the 16-tone code of the ARINC Selcal system. It also communicates with Atscall, a system used in some fleets, which is based on the 16 "touchtone" codes used in telephone systems. As in many ramp testers, battery power is automatically turned off if there is no activity for 15 minutes.

almost never understand it (and they don't need to).

Many pilots are ham radio operators, electrical or computer engineers and can sling technical terms. Nevertheless, don't assume they know the special lingo of avionics.

Switchology First

As you head out to the airplane, be aware that many troubles are caused by the pilot setting switches to the wrong position. This happens even though the pilot flies the airplane regularly.

I once took an airline captain for a ride in a small airplane. He pointed to a blinking light on the panel and asked, "What's that?" I told him that's the transponder reply light. (Hmmm?)

Another time, an experienced corporate pilot said he was getting no power to half his instruments. When a technician checked, he found a bad inverter (which converts battery DC to AC). The technician explained the airplane had *two* inverters and the pilot could have switched in a good one. Despite long experience the pilot was not aware that he had a "reversionary mode."

So the first item to look for when investigating most complaints is the correct setting of all switches and knobs, especially in the audio panel and for powering radios on and off.

Ramp Testers

A lot of diagnosing is done by eye, ear and knob adjustment. Radios produce many symptoms that warn of trouble if you read them. Once these clues are followed, ramp testers narrow down the problem. Let's consider informal checks on the ramp.

ADF

Compass Locator

A quick check of an ADF (Automatic Direction Finder) can be done at an airport with an ILS (instrument landing system). Many ILS's have a compass locator to mark the final approach fix about five miles from the touchdown point. Because the compass locator operates the ADF receiver, it may also serve as an approximate test signal.

You will need to know the frequency, location and ID of the compass locator. This information is on an approach chart which should be available from any IFR pilot who uses the airport. The chart also shows where the ADF needle should point from your location on the airport.

ADF Antenna Tester

This test box measures loop and sense antennas of an ADF receiver. The antenna is mounted inside the box and stimulated by test signals. A 10-inch dial on the simulator is rotated to measure bearing within a 1/2-degree over 360 degrees. These tests once required a shielded room. The tester shown here is the TIC CES-117A.

Broadcast Station

If there are no nearby NDB stations or compass locators, make a quick check of the ADF receiver by tuning to a local AM radio station. You need to know its location to check the bearing. Most AM transmitters are out in the country, and local people often know where the tower is located.

Audio Quality

Tune to a station and turn up the volume. Is the audio distorted? Clear audio must be present for the ADF to perform its job.

An ADF operates from two antennas; a loop for finding a bearing to or from the station and a sense antenna which enables the needle to point toward (not away from) the station. Select the sense antenna, which is usually marked "Receive." The signal should be clear and strong. Next, choose the loop antenna, usually marked "ADF". The needle should swing and point to the station.

In-flight Interference

If the pilot reports rough buzzing or static in the ADF audio while in flight, it could be P-static (from precipitation). It's the build-up of static electricity on the airframe that makes raspy sounds in low-frequency radios. Check if each grounding or bonding point between the ADF system and the airframe is clean and secure. Check the condition of static wicks on the wings and tail (described in the section on Precipitation Static). The wicks bleed off charges quietly into the atmosphere.

Servo Tester

Electronic Aviation Systems

The Model 101A checks autopilot servos and flight control sensors without removing them from the airplane. It measures control voltages to within 5 thousandths of a volt.

Antennas

Doubler

This back-up plate under many aircraft antennas needs to be checked for tightness. Looseness allows moisture to enter and corrosion to form, which degrades antenna performance.

Is there still a watertight seal around the base of the antenna? Reseal this if necessary.

Coaxial Cable

Check the underside of the antenna for a clean connection where the cable connector attaches. Corrosion in the connector is a cause of poor radio performance.

If there is excess coaxial cable below the antenna, don't coil to too tightly. Inspect the cable for cracks and abrasions.

Antenna VSWR

A valuable test for determining the condition of a transmitting antenna is VSWR, for voltage standing wave ratio. It not only checks efficiency of the antenna, but cable and connectors, as well.

VSWR is a measure of how well the transmitter is applying power into the transmission line, then how efficiently the line transfers power into the antenna. For the most efficient transfer, all components must be "matched." In aviation, the standard for matching is "50 ohms," which refers to the electrical load, or "impedance" of each device. Thus, the transmitter is designed for a 50-ohm output, the cable is manufactured for 50 ohms (impedance) and the antenna is fed at a point that is electrically 50 ohms. In such a system, if the transmitter generates 10 watts of radio-frequency power, then nearly 10 watts should flow in the antenna (less a loss in the cable, which we can ignore).

This is close to a perfect system. As the antenna ages, cables crack, connectors corrode, connections no longer make good contact. Some cables are crushed or coiled too tightly and their wires lose correct spacing. At these points, the cable is no longer 50 ohms but some other value. Now when radio energy hits these areas, part of it reflects back to the transmitter and subtracts from the power going to the antenna. The relation of forward and reflected power is known as VSWR, or "voltage standing wave ratio." VSWR can be easily measured and used to determine the condition of the system; the higher the VSWR, the poorer the performance of the antenna system.

Practically speaking, if VSWR is less than about 2.5 to 1 (written as 2.5:1), this is considered acceptable in antennas operating below 200 MHz. A VSWR of 2.0:1 means about 90 percent of the power is getting through.

RF Wattmeter

A portable RF wattmeter is often used for troubleshooting antennas. It is inserted into the transmission line, where it reads forward and reflected power, and indicates VSWR. It can also isolate problems. If the antenna is disconnected and a dummy load installed, the wattmeter reads the condition of the cable. (The dummy load turns RF energy into heat.)

Forward power indicated by the RF wattmeter is from the transmitter, and should be close to the radio manufacturer's specification for this transmitter.

Autopilots

Cable Tension

This critical value is measured with a cable tension meter. Incorrect tension is the source of many autopilot complaints, and it applies to both the main and bridle cables.

Porpoising

In this autopilot problem, the airplane flies a path like a dolphin swimming in a series of arcs. Check cable tension and also the electrical adjustments on the autopilot computer as recommended by the manufacturer.

Examine the cables for broken strands. This is done by *slowly* running your fingers over the cable and feeling for sharp points.

Capstan

Look at this component for signs of wear.

Com Transceivers

During the tests described below, be sure all switches are set to the correct positions, especially those on an audio panel that controls two navcom transceivers. Turn up volume controls and select whether you will listen through the cabin speaker or headphones.

No Receive

When a pilot reports "no communication" on a VHF radio he often means he can't hear anybody on the receiver. The other half of the radio---the transmitter---may be OK. Since this is an important clue to a com problem, turn on the radio and transmit. Signs of a working transmitter include: transmit indicator lights, you hear the signal on a portable aircraft radio, a test monitor, radio-frequency wattmeter or other ramp tester.

Mobile Calibration Lab

Collins

Regulations require that ramp and bench test equipment be calibrated and certified, usually once a year. Many shops send their equipment to calibration laboratories, but another choice is a mobile cal lab. It drives to the shop and performs the work just outside the premises. It also may repair to restore equipment to required accuracy.

If the transmitter is operating it's a good sign the antenna and coaxial cable between radio and antenna are OK. Primary power is also reaching the radio, and there's no problem in the circuit breaker. So far, these signs point to a problem inside the receiver.

Squelch

Operating in the receiver, the squelch silences annoying noise when no signal is being received. Early com radios had a manual squelch that required the pilot to adjust the knob until the noise just disappeared when no signal is received. This caused a lot confusion because too-high a squelch setting caused the receiver to miss incoming signals. Much of the problem was overcome when receivers came fitted with automatic squelch circuits that are self-adjusting. However, receivers now usually include a "test" button that disables the automatic squelch, enabling you to hear the receiver at full sensitivity. If this causes a rushing noise ("static") or voices of other aircraft, it's a sign the receiver is functioning. If no noise is heard on the squelch test (and the radio transmits OK), the problem may be within the receiver. It may simply require a new setting on an internal squelch adjustment by a bench technician.

Let's say the pilot complains he can receive and transmit OK, but something keeps "breaking" the squelch---opening and closing it rapidly, with pulse-like noise. Determine whether it is happening to both navcom radios simultaneously. If it is , the problem is most likely interference from the outside. Next, find out if the problem happens wherever the pilot flies. If the noise follows the airplane, it's probably being generated aboard the airplane, with the most likely sources the magnetos, spark plugs, strobe lights or dirty alternator slip rings.

In some cases, noise breaking through the squelch is eliminated by having a bench technician raise the squelch threshold. The problem is that the radio can also miss very weak signals. The best approach is for the internal adjustment be made to the manufacturer's instructions, using a calibrated bench tester.

There are occasional reports of the squelch breaking open while taxiing on an airport surface. This is often caused when the airplane rolls over electrical cables buried underground. Unfortunately, the cables carry powerful currents to flashing lights for approach and landing guidance. Nothing can be done about this, but it lasts for only a few minutes and disappears after take-off. This underground wiring may also put "dots" on the screen of a Stormscope because they resemble lightning signals. The pilot should expect this and clear the screen. If there is actual lightning activity, it should be visible after lift off.

No Transmit

A leading cause of an inoperative transmitter is not the transmitter, It's the microphone, which contains the push-to-talk switch. The worst offender is the mike that fits in a hangar on the panel. Each time the pilot pulls it from the hangar, then hangs it up, the cable flexes two times. Although the wires are flexible, they break, so pressing the mike button no longer keys the transmitters.

Automatic Test Equipment

Aerospatiale

Automatic Test Equipment (ATE), like this ATEC 5000, checks digital circuits in airliners and military aircraft. It contains programs that automatically test hundreds of parameters. To locate intermittent problems, the test station runs continuously until a fault appears. The time and location of the fault are stored for later viewing by the technician. ATE systems like these are usually found at large airline and repair depots.

Air Data Test

Air data test set by Aerosonic. It checks altimeter, encoding altimeter, airspeed, Mach airspeed, rate-of-climb and cabin pressure. The hand-held remote (at the bottom) enables the technician to sit in the cockpit and observe the instruments while operating the tester located elsewhere. Operating limits can be set to avoid delivering excess pressure to the instruments.

The trend among pilots is to headsets with a boom mike that is not handled. This reduces flexing, but wires are still vulnerable as the pilot turns his head. Because a few strands of wire can disable all transmitters aboard the aircraft, no pilot should fly without a spare mike.

The mike wire almost always breaks where it enters a plug or the microphone case--- because that's where it receives the greatest strain. Quite often, you can press the transmit button, wiggle the wire at these two weak points and, suddenly, the radio begins working as the broken ends touch.

The cable is repairable if the plug can be disassembled. The damaged section is cut short and the wires reconnected. Most modern plugs, however, permanently mold the wire into the cable and cannot be opened. In this case, a replacement cable is ordered from the manufacturer.

DME

Distance Measuring Equipment develops faults such as an inability to lock onto a station. Turn up the DME audio and listen for the Morse code ID (it may take up to 45 seconds to hear). This is a check on the receiver portion and proves it is properly channeled by the VOR receiver.

If you don't hear DME audio be sure your switch positions are correct; the DME may be channeled by several receivers so choose the correct one. If you still can't get DME audio, the transmitter could be defective. Because the DME receiver and transmitter use one antenna, good reception is an indication the antenna and cable are OK.

Complaints about errors in ground speed or time to station are sometimes traced to poor antenna connections. Check the coaxial cable, connectors, antenna hardware and for good bonding and grounding.

ELT-Emergency Locator Transmitter

Test in Aircraft

For the purpose of checking, you may activate an ELT in an airplane under the following conditions. First, tune an aircraft com radio to the emergency frequency of 121.5 MHz, and turn the volume to normal listening level.

1. Perform this test only on the ground, not in flight.
2. Turn on the ELT only during the first five minutes after the hour, for example; between 1:00 PM and 1:05 PM.
3. Listen for the sweeping audio tone (sounds like *"peee-owww---peee-owww"*). Allow only three sweeps to sound, then switch off the ELT.

Because the ELT antenna is within a few feet of the com receiver, the audio should be loud and strong. No audio means the ELT is dead. Weak audio suggests a spent battery, a defect in the antenna or problems in the coaxial cable. ELTs are required to carry a label for the date of battery replacement, so check if it's current.

If you hear a weak signal, turn off the ELT and listen. Because there have been so many false alarms with early ELT's you might be hearing signals from another airplane at your field.

Glideslope Receiver

There are no pilot controls for selecting a glideslope frequency. When an ILS is tuned on a VHF nav receiver, the glideslope receiver is automatically channeled to the correct frequency. Thus, a glideslope problem could be failure of the nav receiver to control the glideslope receiver.

The glideslope has no audio identifier. Because glideslope signals occupy such a narrow path to the runway, the only practical way to troubleshoot is with a ramp tester.

Glideslope signals are high in frequency and depend on good antenna and cable connections. In a light aircraft, the glideslope signal is often tapped from the VOR antenna on the tail through a splitter. Loose or dirty connections cause signal losses. The glideslope antenna in large, transport aircraft is in the nose.

The technician should warn the pilot about using a glideslope in actual instrument conditions. Many pilots don't fully understand the function of the "flag," which could be dangerous. The flag is in a small window next to the glideslope needle, usually with a red-striped symbol (a "barber pole"). If the signal is adequate, the flag is pulled, that is, it moves out of view and assures the pilot the glideslope is working. But there have been accidents where the glideslope receiver did not work---causing the needle to lie in a horizontal position. Unfortunately, this is the same indication as when flying a perfect glideslope. It is important for the pilot to not only check the flag for a good signal, but watch for small needle movements while flying the glideslope.

Lightning Strikes

The aviation industry is more concerned about lightning as airplanes convert from analog to digital avionics. Digital signals are lower in strength and more susceptible to interference. As a result, new requirements were developed to harden the new electronics against outside disturbance.

These requirements emphasize shielded enclosures, shielded wiring, bonding and grounding to protect wiring and circuit components.

RF signal Generator Nav 2000 by BFGoodrich.

Cat III Tester

Ramp test set for checking a Category III ILS aircraft receiver. It generates a variety of signals such as VOR, glideslope, localizer, and marker beacon, as well as autopilot and flight director. The tester is operated by one person in the cockpit while the aircraft is on the ground. Shown here is the Model T-30D by TIC.

Lightning Damage

When lightning strikes an airplane, it causes a current flow in the skin. The energy generates electromagnetic fields that move inside the airplane, where they induce additional current flows in wiring and electrical equipment. Known as "lightning indirect effect," it can trip circuit breakers, disrupt digital circuits and damage other components.

Lightning may damage the skin. After landing, the pilot notices small pits or burns where lightning entered or departed. In some instances, instruments in the panel are damaged. Compasses have been known to demagnetize and swing aimlessly.

One phenomenon is when the pilot sees windshield frames start to glow. During one incident, the glow entered the cockpit, formed a ball and moved up the passenger aisle. The effect is "St. Elmo's Fire," built up by static electricity as the airplane moves through a charged atmosphere near thunderstorms. St. Elmo's is not believed to be dangerous in an airplane (but certainly an unwelcome experience for the passengers).

Loading. After an installation, the airplane is loaded with the latest software before delivery to the customer. In General Aviation aircraft, it is often done by inserting a memory card into a slot on the radio (usually for a navigation database). Future upgrades are done by the pilot.

In air transport, software is more extensive and done differently. Airliners such as the Boeing 737-600 through -900, the 747-400, the 767 and 777 use on-board loadable software. Not only can software update operational data, but upgrade avionics to meet new requirements, make improvements in design and fix errors. Because there are no hardware changes, the job might even be done during the short turn-around time at the gate.

Typical loading time for the six main (EFIS) displays on a 747-400 is 90 minutes.

Software transfer. There are several systems for loading software on an airliner. The aircraft may have a permanently-installed loader on board, or a portable loader carried by the technician and plugged into the aircraft. The Boeing 777 has a maintenance access terminal (MAT) with a mass storage device which also stores spare copies of loadable software.

If the LRU (line replaceable unit) is in a maintenance shop, loading is accomplished with automatic test equipment (ATE). Another approach is connecting to a port on the LRU that accepts a memory disk. It is common in the airlines for the avionics manufacturer to provide a spare copy of software, which is stored aboard the airplane in a binder.

Transponder

The first symptom of a malfunctioning transponder is often a complaint from an air traffic controller. If you are flying IFR or receiving flight following, your blip is on someone's radarscope. When you're told the code is wrong, immediately check the transponder knobs for the correct code selection, especially if any are caught between numbers.

Mode C, or altitude reporting, can also go wrong, showing you at the incorrect altitude. Some pilots believe the transponder altitude they report is taken from the altimeter, and that changing the baro setting will change the reported altitude. The transponder only utilizes its own altitude reference, which is preset to 29.92 inches of mercury, or sea level pressure on a standard day. When this is received by an air traffic control facility, it is automatically corrected for local sea level pressure.

There is too much room for error, it was decided, to let each pilot set his own local pressure in the transponder. Before a transponder is installed (or returned to service) the technician sets the internal pressure sensor to 29.92 inches of mercury.

In reporting a bad transponder it is helpful if the pilot can tell the technician which altitudes were said to be in error by the controller. It may simplify the repair for the technician on the workbench

Because a malfunctioning transponder can interfere with the flow of air traffic, it must be checked by a technician every two years.

The ident button of a transponder is on the front panel, but sometimes a second button is mounted in the yoke (to make it easier for the pilot). If you receive a complaint that the transponder is "identing" at the wrong time (the controller didn't ask for it) there may be a short in the yoke switch. Because the yoke is in frequent motion during flight, wires to the yoke button may fray and rub against a metal ground---which triggers the unwanted ident.

The transponder antenna is critical for good operating range. Because it mounts on the underside of the airplane, it is subject to dirt, grease and contamination. It needs to be clean and well-bonded to the airframe for high efficiency.

Transponders often have a "test" button, which mainly checks the reply lamp.

Ramp Data Loader

Tech S.A.T.

Flightline portable test set loads software on airplane through port in wheel well. It also contains fault diagnostics and flight data analysis. The tester's operating system is Windows-based.

VOR Receiver

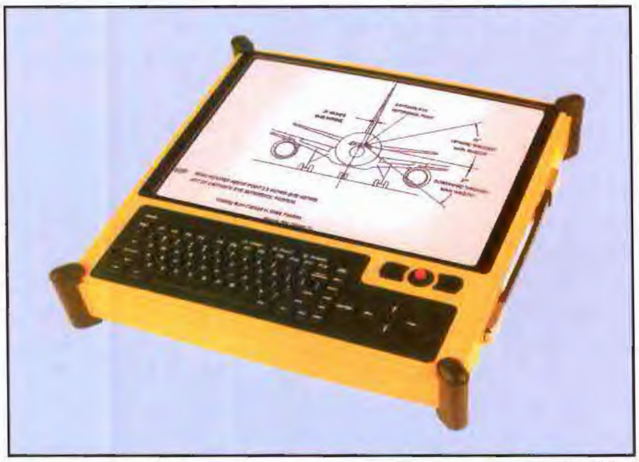
30-day Test.

To operate an aircraft under instrument flight rules (IFR) its VOR receiver must be checked within the last 30 days. The tests described below are mostly for the pilot to perform and log. The technician usually has a portable ramp tester for generating test signals, but may also make informal checks with the following resources:

VOT (VOR Test Facility)

The VOT is a special station found at large airports that transmits a test signal. Tune the VOR receiver to the VOT frequency (usually on 108 MHz) and adjust the Omnibearing Selector (OBS) until the needle (CDI, course deviation indicator) centers. The course indicator will read either 0 degrees, with the flag indicating FROM---or 180 degrees, and the flag indicating TO.

Either reading should not be greater than plus or minus 4 degrees from the desired setting (0 or 180 degrees). If the pilot makes this check in the air, the allowable error is plus or minus 6 degrees.



Demo Systems

Portable Data Loader contains a mass storage cartridge to upload software directly into the aircraft. It also downloads maintenance data recorded during flight. This information can be analyzed in the shop. The loader meets the ARINC 615 spec.

VOR Receiver Checkpoint

Some large airports use a nearby VOR station (within several miles) as a reference for checking a receiver. A location on the airport is marked with a sign giving VOR identification, frequency and radial. The airplane is taxied to that point, the radio tuned and the error observed. It must not be more than plus or minus four degrees.

Two VORs

If there are no test stations like those described, it is acceptable, where possible, to tune two VOR receivers to one VOR station. The error between them should not be more than plus or minus four degrees.

If this test is done in the air, however, the acceptable error increases to 6 degrees.

Transponder Tester

Aeroflex

The IFF-701 is a flightline transponder tester. It performs single checks or an autotest that runs 30 tests automatically. The tester communicates with the aircraft through its antenna. The red object at the lower left is an antenna shield, which covers one aircraft antenna in installations where there are two transponders (in an anti-collision, or TCAS, system).

VOR Indicator

If the pilot reports a dead VOR needle---no movement at all---turn up the nav volume and listen for the Morse Code (or voice) identification. If none is heard and the signal is strong (the flag is "pulled," meaning not visible)---there is probably a fault inside the receiver. If ident audio is heard, but the needle won't move, that is also an internal receiver problem.

Sometimes the problem is a needle that moves erratically, darting left and right. This is often due to an internal component (a "resolver") that turns with the omnibearing selector (OBS). If the resolver gets dirty it "skips" and causes the needle to jump unpredictably. This requires a bench repair.

If everything looks good---To-From and warning (no-signal) flags behaving correctly, with good Ident audio--- the needle may have a burned-out movement.

On rare occasions, a VOR receiver may behave normally, but you hear no Ident audio. Be aware that any time a VOR ground station is being worked on, the technician turns off the audio ident. It warns pilots not to use the station for navigation.

Course Bends and Scallops

A pilot is flying and notices his VOR needle swinging from side to side. If it happens slowly, it's called "course bends"; if occurring at a rapid rate, it's "course scalloping." In many instances, the problem is at the VOR ground station. When the signal is broadcast through mountainous areas, it is bent by reflections---and they show up on the VOR needle. Because these signal deviations cannot be completely eliminated, the government agency controlling the VOR issues a notice to airmen (notam) stating that certain radials of a VOR are unusable. However, it may be considered usable when the error is not more than 2.5 degrees for enroute navigation and 1.5 degrees for a VOR approach.

Windshield Wipers

A different problem occurs when the pilot is flying via VOR and notices the needle swinging back and forth. If he puts two VOR radios on the same station, both needles move together like windshield wipers. This is caused by propellor or rotor modulation. The signal arriving from the ground station moves through the propellor and is "chopped" in the spinning blades. If the chopping rate is close to that of the signal modulation (usually 30 times per second) the two will mix and produce a difference signal---which causes slow movement of the needles. If it's a prop plane, and the effect disappears when a VOR from a different direction is selected, that's a good sign of propellor modulation.

Rotor modulation in helicopters, on the other hand, is more troublesome because the rotor blades cover a large area. They act as electrical mirrors, causing the arriving signal to split into two parts; one is direct from the station, the other is the reflection off the rotor blades. The two signals mix and produce a third, which causes VOR needles to drift back and forth.

Avionics manufacturers recognize the problem and provide filters in radios intended for helicopter operation.

In a prop plane, be sure the VOR antennas are mounted in a location suggested by the airframe manufacturer. In some instances the windshield wiper effect may be reduced by making small changes in engine RPM.

Glideslope

Although the glideslope operates on its own receiver, it displays information on the horizontal needle of the VOR indicator. When a pilot complains of missing or erratic glideslope operation, ask if it happens only at certain airports. The reason is, when the VOR receiver is set to an ILS frequency, the glideslope receiver is "channeled" to its operating frequency. (ILS and glideslope frequencies always acts in pairs.) A defect in the VOR channeling circuit may cause this.

Unlike most ground navaids, no audio ident is transmitted for the glideslope. The GS flag---which is pulled when signal strength is adequate---provides another clue to problems. Most troubleshooting on the ramp, however, should be done with a portable tester that simulates a ground station and exercises all functions of the receiver.

Wiring and Connectors

Inspecting for Wear

After a time in service, wire bundles sag, rub and chafe, causing electrical problems--or even obstruct flight controls. A careful inspection reveals these trouble areas. Give special attention to wire supporting points, such as tie-wraps, clamps and grommets. Unsecured wires that hang in loops are dangerous.

Cut Wires

Old airplanes modified with new avionics often have wires that are simply cut off and go nowhere. The technician rarely removes old cables that are no longer used, but snips them. Such unused wires usually pose no hazard, but their ends should be insulated with crimp-on splices or tubing.

Fasteners

Nuts and bolts that secure wiring to the airplane have lock washers or other means to resist vibration. But they loosen and allow the wire bundle to move. Check and re-tighten any suspicious hardware. Reposition wiring before tightening to keep it clear of any hazards.

Oxidation

The large temperature changes in an airplane as it flies through different altitudes causes condensation and corrosion on metal fasteners. Look for powdery deposits on hardware and replace any that have deteriorated.

This is also important for a bonding or ground connection, where a cable is bolted to the metal airframe. Corrosion in that joint creates several problems that are difficult to analyze, such noisy radio reception. If hardware is discolored, it should be removed and shined with fine sandpaper or replaced if necessary.

Discoloration

Wiring insulation or any device that has darkened or changed color could be overheating. Determine the source---insufficient cooling, a radio drawing excessive current, or proximity to a hot area, for example.

Avionics Enclosures: Intermittent

A pilot reported that a panel-mounted radio "cut out" during certain times but played perfectly during others. The technician asked, "Does it happen in a climb?" When the pilot replied, "Yes," the problem was identified. During a climb, the radio case slipped out of the rear connector, then back in during level flight. (It took only a few thousandths of an inch to break the circuit.)

It is not unusual for the locking mechanism of a radio housing to loosen after many hours of flight. Thus, one of the first steps a technician might take when checking a dead radio is to simply press a hand against the face and push in. If the radio begins to play---problem is apparent. But not always. Tightening the locking screw should draw the radio into its tray and push the connector pins into their sockets. That works if everything is in perfect alignment; tray, radio and connectors. But old airplanes are not perfectly square. When re-seating the radio in a tray push the radio into the rack with your hand, and press it home into the connector. With your hand still applying pressure, tighten the locking screw. Now the screw does not have to overcome a lot of resistance and the rear connections can make good contact.

Remote Radio Racks

In large aircraft, where the radio has a remote-mounted unit, there have been many problems with trays and connectors. Because airlines found this very costly, they pressured the connector industry come up with improved designs. Not only are new locking mechanisms simple to operate, but may have clutches to prevent overtightening. Nevertheless, there are still instances of technicians failing to lock the tray in place. It's a good idea during an inspection to check remote boxes to see if they are secure in their mounting.

Some remote units will move because they shock-mounted. There are rubber mounts that absorb vibration and are mainly used for electromechanical instruments (with gyroscopes). Today, there are fewer shock-mounts in avionics because microelectronics are not as susceptible to shock. This includes later generations of gyroscopes which replace "spinning iron" wheels with laser beams or miniature accelerometers. Even small aircraft are replacing old gyro systems with solid-state sensors to operate flight instruments.

Fault Detection Device

Problems are pinpointed along a wiring run with an instrument like this Fault Detection Device. The connection is made only to one end of the wire under test. The instrument sends an electrical pulse into the wire, which reflects back from where the wire is broken, shorted or defective. This is pictured on the screen (below) which gives distance and location of the problem. Accuracy can be within 1 inch of the fault.

These testers are also known as "TDRs," for time domain reflectometry.

(Honeywell)

IFR 4000 portable navcom ramp tester .

Boeing

The laptop PC is part of the Boeing "Portable Maintenance Aid." It reduces time to troubleshoot by providing necessary documents, along with search capability. The system places the following at the technician's fingertips; fault isolation manual, aircraft maintenance manual, illustrated parts catalog, wiring diagrams, equipment list, maintenance tips and service letters. Nearly all Boeing aircraft are covered by the Portable Maintenance Aid and it's in use by many airlines.

Precipitation (P) Static

P-static is a form of interference caused by the buildup of electrical charges on the airplane as it flies through rain, snow, dust, ice crystals or clouds. The friction of the airframe against these particles generates static electricity. When voltage increases sufficiently, there is a "corona" discharge; a spark jumps to the surrounding atmosphere. This generates radio waves which reach aircraft antennas and are heard as noise.

Even non-metallic parts of the airplane may become charged; windshields, radomes and plastic panels, for example. This causes a discharge known as "streamering," which couples radio energy to the metal airframe and then to the antennas.

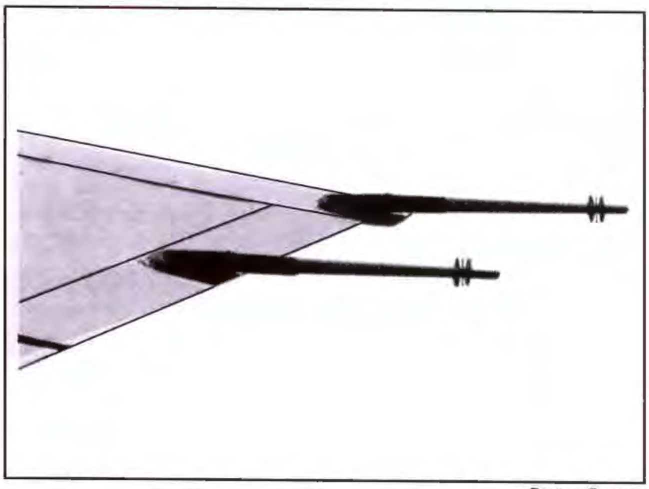
Interference is most prominent at lower frequencies, mostly affecting the Automatic Direction Finder, Loran and High Frequency (HF), but can reach up to the VHF com and nav bands.

The problem is treated with "static dischargers," popularly known as "static wicks." They're based on the principle of high voltage seeking to discharge from a sharp point. Many static wicks consist of thousands of fine carbon points which bleed off the charge at a lower voltage, thus reducing interference. Some models have only one point. The wicks also contain high resistance to keep sparks from coupling back to the airframe.

Maintenance Because static wicks are out in the airstream, they erode and need regular inspection. The manufacturer may recommend resistance checks between the tip of wick to the base of the discharger. In some models, the wick turns gray and needs to be trimmed back to expose a fresh surface.

Any static discharger depends on a good bond (ground) between its base and the airframe; the resistance must be extremely low. If corrosion appears, the mounting needs to be cleaned.

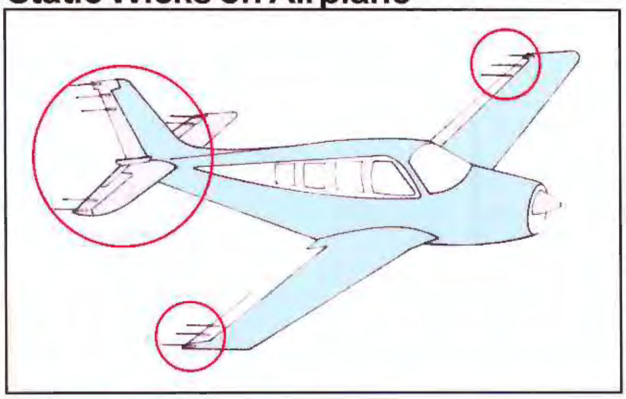
When an airplane goes to the paint shop, static wicks are often removed. After the job, the wicks may be re-installed *over* the new coat of paint! This makes the wick useless. A close inspection shows this condition, which must be corrected by removing paint under the wick mounting.



Dayton-Granger

Static wicks reduce P-static by drawing the electrical charge from the airframe and discharging it quietly into the atmosphere. The construction of the wick produces a lower "corona," or discharge, voltage than the airframe.

Static Wicks on Airplane



Typical locations are shown for static wicks on trailing edges of wings and tail. Manufacturers of wicks provide drawings for most aircraft that show exact locations.

Diagnostic Instrument

This test instrument generates high voltage to simulate static discharges built up in flight. The technician applies voltages at or near antennas, trailing edges, de-icing boots and other points that might cause sparks and other interference. He can sweep the whole airframe to determine areas where bonding is poor, a condition that encourages discharges. Windshields, radomes and other non-metallic surfaces can be charged to locate these noise sources. This electrostatic diagnostic test instrument, produced by Dayton-Granger, is used in the hangar without placing insulating blocks under the aircraft.

Avionics Checklist

The more symptoms of trouble provided to the technician, the quicker he can analyze problems. Here is a summary of items for both pilot and technician to help gather that information

Electrical Source

•Are there signs of a failing charging system, such as hard starting, dim lighting or changes in lamp brightness as engine rpm varies?

•Are there blown fuses or "popped" circuit breakers?

•Do you hear a whining or musical tone that varies with engine rpm? This could be alternator interference.

•Is there repeating noise in the audio, or extra dots on a Stormscope? This might caused by a strobe light or poorly shielded ignition wires.

•Is the negative terminal of the battery making a good connection with the airframe?

Com Radio

•Is the correct radio selected on the audio panel?

•Check if the volume control is at normal listening level.

•Are plugs for mikes and headsets fully seated in their jacks?

•If there is no receive audio, check if the push-to-talk switch on the mike is stuck on.

•Are mike and headphone plugs clean and shiny?

•Turn the receiver to "Test" to hear background noise.

*If there's no audio in the headphones, switch to the cabin speaker.

•When trying to contact another station, does the operator say, "I can hear your carrier, but no modulation?"

•Check the frequency the radio is tuned to. Is it in the "Active" position?

•Many radios provide "sidetone;" as you speak. You should hear yourself in the headset.

•Does the indicator lamp light up when the mike is pressed?

•Does the same problem affect two com radios?

•Does the problem occur on more than one channel?

•Is the audio distorted, noisy?

* Are there audio tones behind your voice when transmitting? (This could be inverter or alternator interference.)

Transponder

•When flying in a radar environment, does the reply light blink? Check if the light is not set to the dim position.

•Press the test button to check reply light.

•Turn off the DME. If the transponder problem disappears, the DME is causing interference.

•Does air traffic control say it's not receiving Mode A (identification) and/or Mode C (altitude)?

•If air traffic control reports problems, try to communicate with another radar facility to confirm it. Sometimes the problem is the radar facility.

•Is the mode selector in the correct position, and not in standby?

•Does the transponder "recycle" correctly. Turn it to standby, then turn it on. There may be about a 30 second delay before it turns on again.

Flight Control/Autopilot

•Does it follow the selected mode, such as wings level, heading hold, and track the VOR or Localizer?

•Does it track the vertical functions, such as altitude hold?

•Is the autotrim responding correctly?

•Is there "porpoising"---where the nose rises and falls.

•Can trim be adjusted?

•Check the vacuum for the gyro instruments.

•With the autopilot engaged, and the airplane on the ground, can you overpower the system with the flight controls?

•Are control cables loose?

Weather Radar

•Check the condition of the radome for cracks, water entry, splitting of layers.

*Verify the setting of panel controls, such as brightness and sensitivity.

•Run the self-test routine

•Are display graphics sharp and clear?

•Does the radar stabilize as the aircraft maneuvers?

GPS

•Is the database current?

•If the GPS is relocated more than several hundred miles with the power off, expect it to do a sky search of five or more minutes before navigating.

•Are there enough satellites for navigation? Three is the minimum, while four are required for instrument flight.

•When on the ground, is the GPS antenna shaded by hangars or other structures?

•Check the mapping of the satellites. Are there sufficient satellites widely dispersed for good geometry?

•Check for sufficient signal strength.

•Have any warnings been issued (notices to airmen) that affect satellite coverage. Are there forecasts of severe solar storms which might affect reception?

•Does the position shown on the GPS agree with the airplane's present location?

•Is the airplane in a hangar where GPS signals may not penetrate?

•Are error messages present?

Distance Measuring Equipment (DME)

•Listen to DME audio for a Morse code identifier.

•Is the brightness turned up for the display?

•Be aware that ground speed and time-to-station function only when the airplane is flying directly to or from the ground station.

•Is the DME station off for maintenance? Check another station.

Automatic Direction Finder (ADF)

•Does interference disappear when the engine is off?

•Does the ADF needle point when "ADF" is selected and a station is tuned?

•Is the bandswitch set to the correct band?

•Do you hear audio when "Ant" is selected, a station is tuned, and there is no ADF needle movement?

•Is the bearing of the pointer accurate?

•Is the ADF needle being deflected by thunderstorms (which may be more than 100 miles away)?

•Does the test function deflect the ADF needle an appropriate number of degrees?

•Did you check for ADF action on more than one station?

Nav (VOR/ILS)

• Can you hear a Morse code and/or voice identifier?

•Does the problem appear on more than one channel?

•If reception is poor, is it true for all directions?

•Are both VOR and Localizer functions affected the same way? Can you receive one but not the other?

•Is the problem the same in a second nav radio?

•Does the VOR bearing appear to be in error?

•Center the VOR needle, then rotate the bearing selector 180 degrees. Is there an error between the two bearings (to and from)?

•Are flags indicating good signal strength?

•Compare two nav receivers to determine if both have the same problem.

Index

Review Questions
Chapter 29 Test and Troubleshooting

29.1 A frequent problem in avionics occurs when the pilot sets switches ______________.

29.2 If there are no nearby NDB (non-directional beacon) stations or compass locators, an ADF may be given a quick check by tuning to ___________.

29.3 When checking an antenna, the VSWR (voltage standing wave ratio) should be less than _____.

29.4 The power output of a transmitter is measured by ____________.

29.5 A quick test of whether a com receiver is working is to disable the squelch (often with the "Test" button) and listening for _________.

29.6 What is a major cause of an inoperative transmitter?

29.7 How can you check if a DME is being correctly channeled by the VOR receiver?

29.8 When can an ELT be tested?

29.9 What should you check first when the glideslope indication is missing or weak?

29.10 Damage from lightning strikes may be reduced by ______________.

29.11 If the transponder code is incorrect, check for ____________

29.12 What is a common problem if the transponder is reported to be "identing" at the wrong time?

29.13 Name three ways a VOR receiver can be checked for accuracy without a ramp tester.

29.14 What are (A) the cause and (B) the cure for "windshield wiper" movement of a VOR needle?

29.15 What should you suspect when a radio cuts out when airplaue climbs?

29.16 How do you reduce noise from Precipitation (P) static?

About the Author

Len Buckwalter started Avionics Magazine and served as Publisher and Editor for 17 years. Earlier, he specialized in aviation and electronics, having written over 2,000 magazine articles and 22 books. His articles have been published in Air Progress, Kitplanes, AOPA Pilot, New York Times and Rotor & Wing. As one of the first to use the Internet, he started **www.avionics.com** in 1993 to launch *Avionics Library*, a publisher of books, CD's and software for the engineer and technician in the avionics industry.

A graduate of New York University, he served in the US Signal Corps as Communications Chief of an air-ground signal battalion, constructing and operating communications systems. Mr. Buckwalter was President of Avionics Center, an FAA-certified repair station in Leesburg, VA.

He is an instrument-rated pilot with 3000 hours' flight time and holds an FCC license for the repair of avionics equipment. His interest in the field began as a teen-ager operating an amateur ("ham") radio station, designing and building most of his equipment.

Flying his own aircraft, he attended the Experimental Aircraft Assoc. convention at Oshkosh for 15 years. He attended numerous conferences of the Aircraft Electronics Association, Airlines Electronics Engineering Committee (ARINC), and Avionics Maintenance Conference (ARINC). He can be reached at len@avionics.com

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