Chapter 1

Human Factors

Introduction

Human factors is a broad field that examines the interaction between people, machines, and the environment for the purpose of improving performance and reducing errors. As aircraft became more reliable and less prone to mechanical failure, the percentage of accidents related to human factors increased. Some aspect of human factors now accounts for over 80 percent of all accidents. Pilots who have a good understanding of human factors are better equipped to plan and execute a safe and uneventful flight.

Flying in instrument meteorological conditions (IMC) can result in sensations that are misleading to the body's sensory system. A safe pilot needs to understand these sensations and effectively counteract them. Instrument flying requires a pilot to make decisions using all available resources.

The elements of human factors covered in this chapter include sensory systems used for orientation, illusions in flight, physiological and psychological factors, medical factors, aeronautical decision-making, and crew resource management (CRM).

Sensory Systems for Orientation

Orientation is the awareness of the position of the aircraft and of oneself in relation to a specific reference point. Disorientation is the lack of orientation, and spatial disorientation specifically refers to the lack of orientation with regard to position in space and to other objects.

Orientation is maintained through the body's sensory organs in three areas: visual, vestibular, and postural. The eyes maintain visual orientation. The motion sensing system in the inner ear maintains vestibular orientation. The nerves in the skin, joints, and muscles of the body maintain postural orientation. When healthy human beings are in their natural environment, these three systems work well. When the human body is subjected to the forces of flight, these senses can provide misleading information. It is this misleading information that causes pilots to become disoriented.

Eyes

Of all the senses, vision is most important in providing information to maintain safe flight. Even though the human eye is optimized for day vision, it is also capable of vision in very low light environments. During the day, the eye uses receptors called cones, while at night, vision is facilitated by the use of rods. Both of these provide a level of vision optimized for the lighting conditions that they were intended. That is, cones are ineffective at night and rods are ineffective during the day.

Rods, which contain rhodopsin (called visual purple), are especially sensitive to light and increased light washes out the rhodopsin compromising the night vision. Hence, when strong light is momentarily introduced at night, vision may be totally ineffective as the rods take time to become effective again in darkness. Smoking, alcohol, oxygen deprivation, and age affect vision, especially at night. It should be noted that at night, oxygen deprivation such as one caused from a climb to a high altitude causes a significant reduction in vision. A return back to the lower altitude will not restore a pilot's vision in the same transitory period used at the climb altitude.

The eye also has two blind spots. The day blind spot is the location on the light sensitive retina where the optic nerve fiber bundle (which carries messages from the eye to the brain) passes through. This location has no light receptors, and a message cannot be created there to be sent to the brain. The night blind spot is due to a concentration of cones in an area surrounding the fovea on the retina. Because there are no rods in this area, direct vision on an object at night will disappear. As a result, off-center viewing and scanning at night is best for both obstacle avoidance and to maximize situational awareness. [See the Pilot's Handbook of Aeronautical Knowledge and the Aeronautical Information Manual (AIM) for detailed reading.]

The brain also processes visual information based upon color, relationship of colors, and vision from objects around us. *Figure 1-1* demonstrates the visual processing of information. The brain assigns color based on many items to include an object's surroundings. In the figure below, the orange square on the shaded side of the cube is actually the same color as the brown square in the center of the cube's top face.

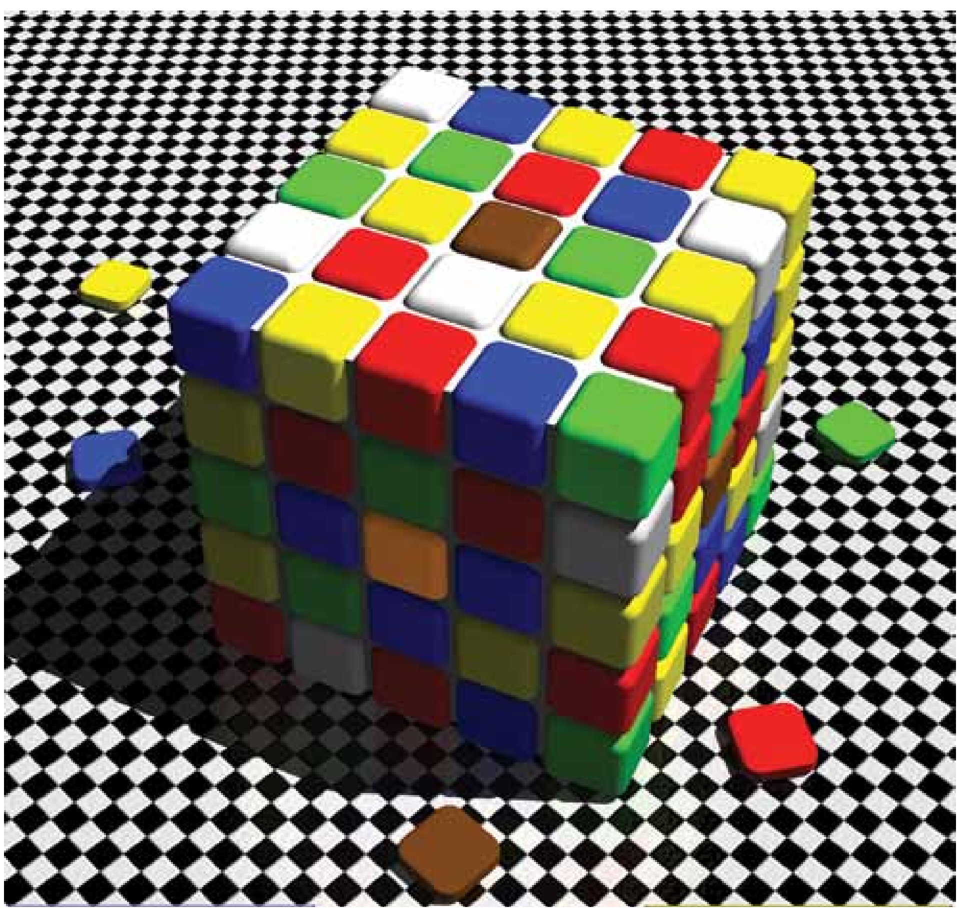

Figure 1-1. *Rubik's Cube Graphic.*

Isolating the orange square from surrounding influences will reveal that it is actually brown. The application to a real environment is evident when processing visual information that is influenced by surroundings. The ability to pick out an airport in varied terrain or another aircraft in a light haze are examples of problems with interpretation that make vigilance all the more necessary.

Figure 1-2 illustrates problems with perception. Both tables are the same lengths. Objects are easily misinterpreted in size to include both length and width. Being accustomed to a 75-foot-wide runway on flat terrain is most likely going to influence a pilot's perception of a wider runway on uneven terrain simply because of the inherent processing experience.

Vision Under Dim and Bright Illumination

Under conditions of dim illumination, aeronautical charts and aircraft instruments can become unreadable unless adequate flight deck lighting is available. In darkness, vision becomes more sensitive to light. This process is called dark adaptation. Although exposure to total darkness for at least 30 minutes is required for complete dark adaptation, a pilot can achieve a moderate degree of dark adaptation within 20 minutes under dim red flight deck lighting.

Red light distorts colors (filters the red spectrum), especially on aeronautical charts, and makes it very difficult for the eyes to focus on objects inside the aircraft. Pilots should use it only where optimum outside night vision capability is necessary. White flight deck lighting (dim lighting) should be available when needed for map and instrument reading, especially under IMC conditions.

Since any degree of dark adaptation is lost within a few seconds of viewing a bright light, pilots should close one eye when using a light to preserve some degree of night vision. During night flights in the vicinity of lightning, flight deck lights should be turned up to help prevent loss of night vision due to the bright flashes. Dark adaptation is also impaired by exposure to cabin pressure altitudes above 5,000 feet, carbon monoxide inhaled through smoking, deficiency of Vitamin A in the diet, and by prolonged exposure to bright sunlight.

During flight in visual meteorological conditions (VMC), the eyes are the major orientation source and usually provide accurate and reliable information. Visual cues usually prevail over false sensations from other sensory systems. When these visual cues are taken away, as they are in IMC, false sensations can cause the pilot to quickly become disoriented.

An effective way to counter these false sensations is to recognize the problem, disregard the false sensations, rely on the flight instruments, and use the eyes to determine the aircraft attitude. The pilot must have an understanding of the problem and the skill to control the aircraft using only instrument indications.

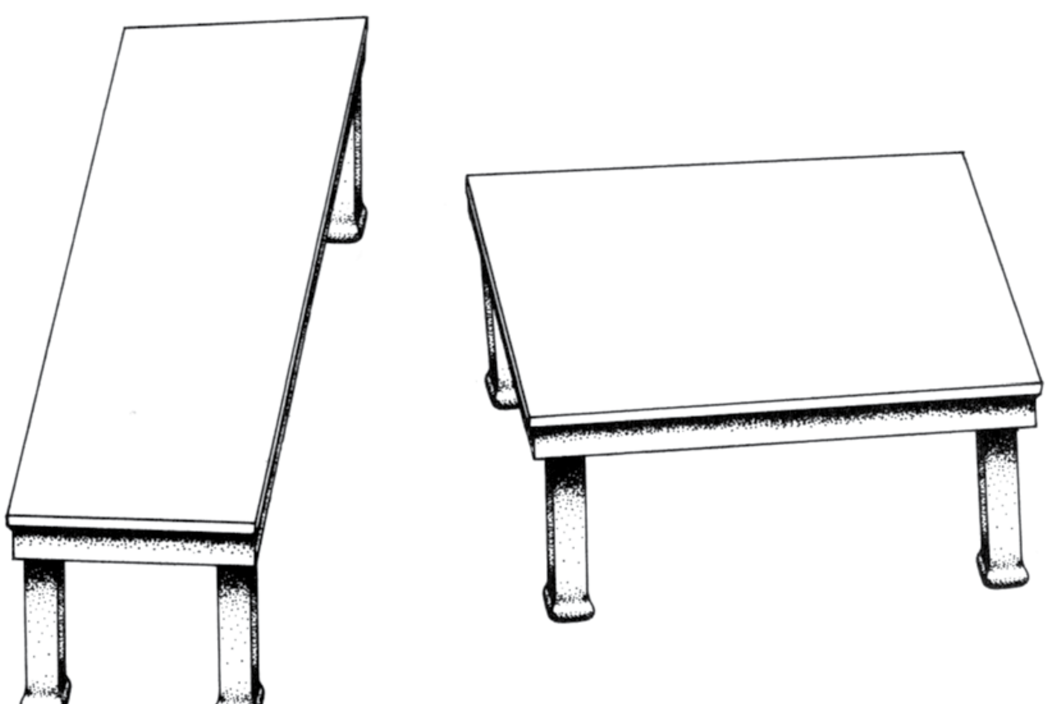

Figure 1-2. *Shepard's Tables.*

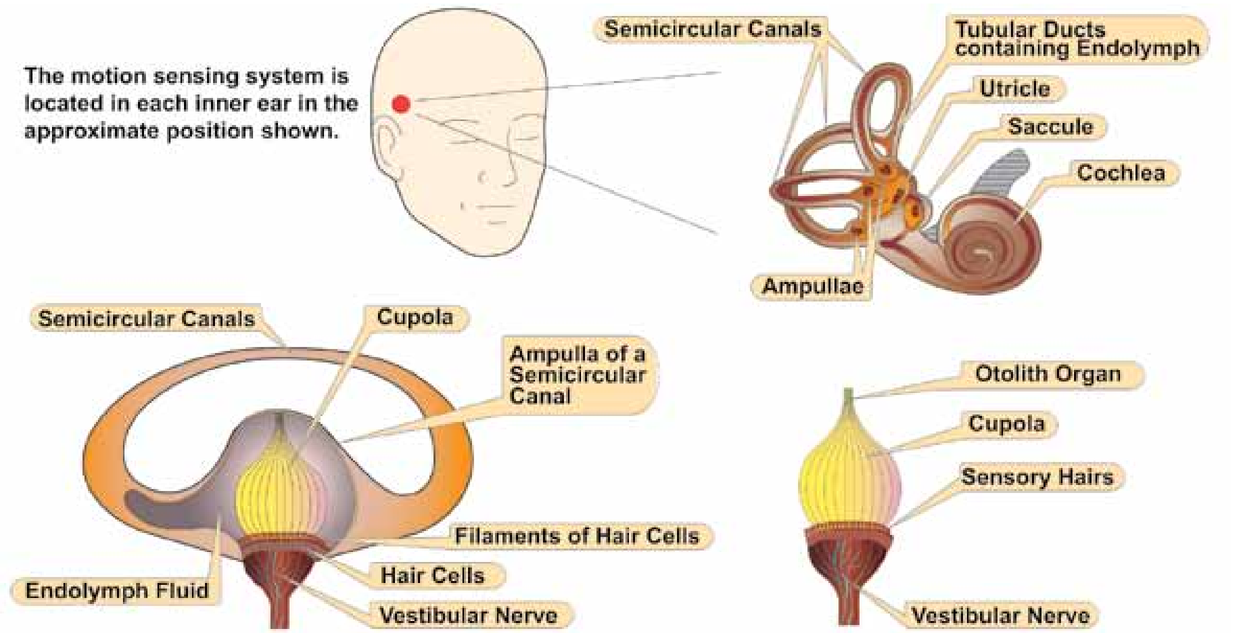

Figure 1-3. *Inner Ear Orientation.*

Ears

The inner ear has two major parts concerned with orientation, the semicircular canals and the otolith organs. *[Figure 1-3]* The semicircular canals detect angular acceleration of the body while the otolith organs detect linear acceleration and gravity. The semicircular canals consist of three tubes at right angles to each other, each located on one of three axes: pitch, roll, or yaw as illustrated in *Figure 1-4*. Each canal is filled with a fluid called endolymph fluid. In the center of the canal is the cupola, a gelatinous structure that rests upon sensory hairs located at the end of the vestibular nerves. It is the movement of these hairs within the fluid which causes sensations of motion.

Because of the friction between the fluid and the canal, it may take about 15–20 seconds for the fluid in the ear canal to reach the same speed as the canal's motion.

To illustrate what happens during a turn, visualize the aircraft in straight and level flight. With no acceleration of the aircraft, the hair cells are upright and the body senses that no turn has occurred. Therefore, the position of the hair cells and the actual sensation correspond.

Placing the aircraft into a turn puts the semicircular canal and its fluid into motion, with the fluid within the semicircular canal lagging behind the accelerated canal walls.*[Figure 1-5]* This lag creates a relative movement of the fluid within the canal. The canal wall and the cupula move in the opposite direction from the motion of the fluid.

The brain interprets the movement of the hairs to be a turn in the same direction as the canal wall. The body correctly senses that a turn is being made. If the turn continues at a constant rate for several seconds or longer, the motion of the fluid in

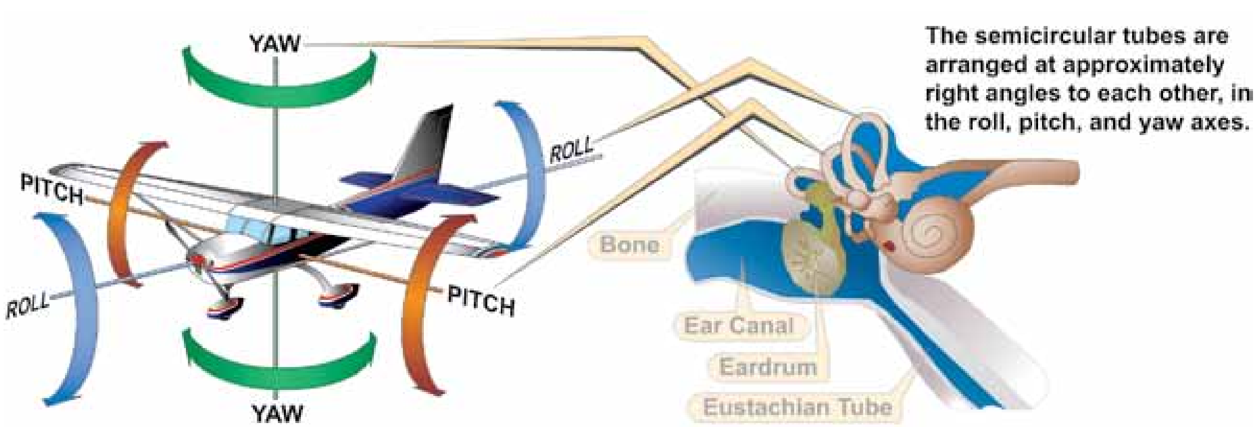

Figure 1-4. *Angular Acceleration and the Semicircular Tubes.*

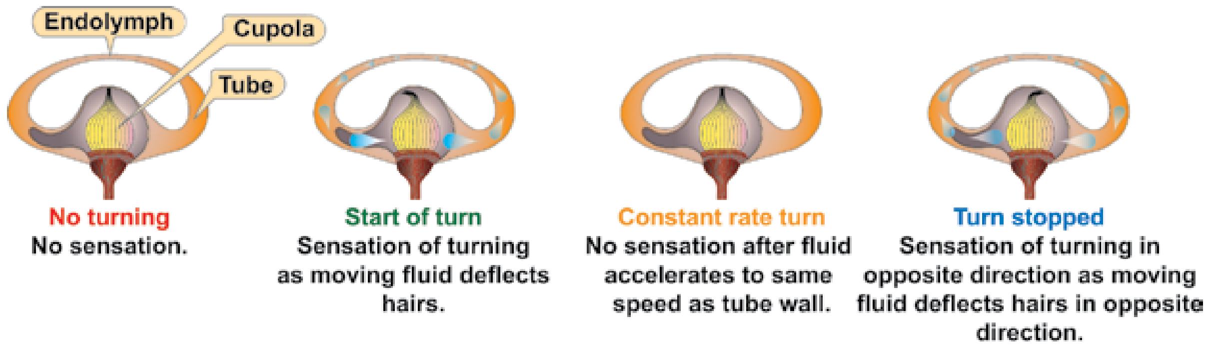

Figure 1-5. *Angular Acceleration.*

the canals catches up with the canal walls. The hairs are no longer bent, and the brain receives the false impression that turning has stopped. Thus, the position of the hair cells and the resulting sensation during a prolonged, constant turn in either direction will result in the false sensation of no turn.

When the aircraft returns to straight-and-level flight, the fluid in the canal moves briefly in the opposite direction. This sends a signal to the brain that is falsely interpreted as movement in the opposite direction. In an attempt to correct the falsely perceived turn, the pilot may reenter the turn placing the aircraft in an out of control situation.

The otolith organs detect linear acceleration and gravity in a similar way. Instead of being filled with a fluid, a gelatinous membrane containing chalk-like crystals covers the sensory hairs. When the pilot tilts his or her head, the weight of these crystals causes this membrane to shift due to gravity and the sensory hairs detect this shift. The brain orients this new position to what it perceives as vertical. Acceleration and deceleration also cause the membrane to shift in a similar manner. Forward acceleration gives the illusion of the head tilting backward. *[Figure 1-6]* As a result, during takeoff and while accelerating, the pilot may sense a steeper than normal climb resulting in a tendency to nose-down.

Nerves

Nerves in the body's skin, muscles, and joints constantly send signals to the brain, which signals the body's relation to gravity. These signals tell the pilot his or her current position. Acceleration will be felt as the pilot is pushed back into the seat. Forces created in turns can lead to false sensations of the true direction of gravity, and may give the pilot a false sense of which way is up.

Uncoordinated turns, especially climbing turns, can cause misleading signals to be sent to the brain. Skids and slips give the sensation of banking or tilting. Turbulence can create motions that confuse the brain as well. Pilots need to be aware that fatigue or illness can exacerbate these sensations and ultimately lead to subtle incapacitation.

Illusions Leading to Spatial Disorientation

The sensory system responsible for most of the illusions leading to spatial disorientation is the vestibular system. Visual illusions can also cause spatial disorientation.

Vestibular Illusions

The Leans

A condition called the leans can result when a banked attitude, to the left for example, may be entered too slowly to set in motion the fluid in the "roll" semicircular tubes. *[Figure 1-5]* An abrupt correction of this attitude sets the fluid in motion, creating the illusion of a banked attitude to the right. The disoriented pilot may make the error of rolling the aircraft into the original left banked attitude, or if level flight is maintained, will feel compelled to lean in the perceived vertical plane until this illusion subsides.

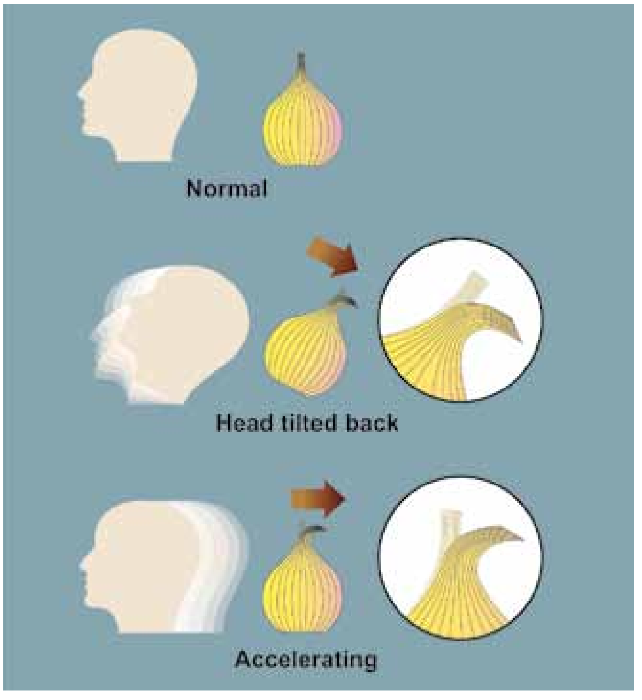

Figure 1-6. *Linear Acceleration.*

Coriolis Illusion

The coriolis illusion occurs when a pilot has been in a turn long enough for the fluid in the ear canal to move at the same speed as the canal. A movement of the head in a different plane, such as looking at something in a different part of the flight deck, may set the fluid moving and create the illusion of turning or accelerating on an entirely different axis. This action causes the pilot to think the aircraft is doing a maneuver that it is not. The disoriented pilot may maneuver the aircraft into a dangerous attitude in an attempt to correct the aircraft's perceived attitude.

For this reason, it is important that pilots develop an instrument cross-check or scan that involves minimal head movement. Take care when retrieving charts and other objects in the flight deck—if something is dropped, retrieve it with minimal head movement and be alert for the coriolis illusion.

Graveyard Spiral

As in other illusions, a pilot in a prolonged coordinated, constant rate turn, will have the illusion of not turning. During the recovery to level flight, the pilot will experience the sensation of turning in the opposite direction. The disoriented pilot may return the aircraft to its original turn. Because an aircraft tends to lose altitude in turns unless the pilot compensates for the loss in lift, the pilot may notice a loss of altitude. The absence of any sensation of turning creates the illusion of being in a level descent. The pilot may pull back on the controls in an attempt to climb or stop the descent. This action tightens the spiral and increases the loss of altitude; hence, this illusion is referred to as a graveyard spiral. *[Figure 1-7]* At some point, this could lead to a loss of control by the pilot.

Somatogravic Illusion

A rapid acceleration, such as experienced during takeoff, stimulates the otolith organs in the same way as tilting the head backwards. This action creates the somatogravic illusion of being in a nose-up attitude, especially in situations without good visual references. The disoriented pilot may push the aircraft into a nose-low or dive attitude. A rapid deceleration by quick reduction of the throttle(s) can have the opposite effect, with the disoriented pilot pulling the aircraft into a nose-up or stall attitude.

Inversion Illusion

An abrupt change from climb to straight-and-level flight can stimulate the otolith organs enough to create the illusion of tumbling backwards, or inversion illusion. The disoriented pilot may push the aircraft abruptly into a nose-low attitude, possibly intensifying this illusion.

Elevator Illusion

An abrupt upward vertical acceleration, as can occur in an updraft, can stimulate the otolith organs to create the illusion of being in a climb. This is called elevator illusion. The disoriented pilot may push the aircraft into a nose-low attitude. An abrupt downward vertical acceleration, usually

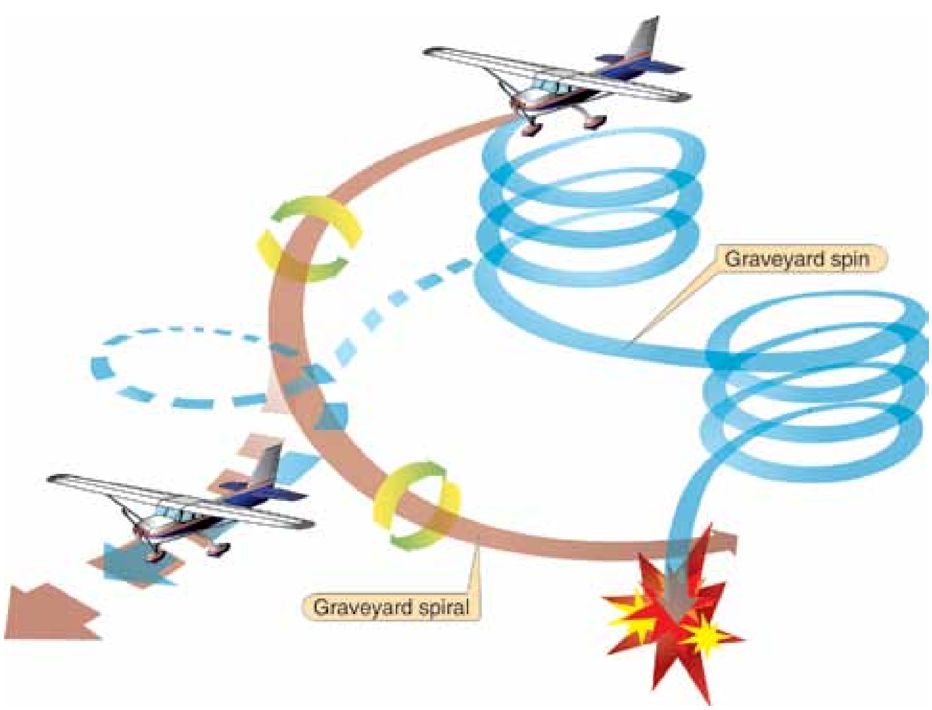

Figure 1-7. *Graveyard Spiral.*

in a downdraft, has the opposite effect, with the disoriented pilot pulling the aircraft into a nose-up attitude.

Visual Illusions

Visual illusions are especially hazardous because pilots rely on their eyes for correct information. Two illusions that lead to spatial disorientation, false horizon and autokinesis, are concerned with only the visual system.

False Horizon

A sloping cloud formation, an obscured horizon, an aurora borealis, a dark scene spread with ground lights and stars, and certain geometric patterns of ground lights can provide inaccurate visual information, or false horizon, for aligning the aircraft correctly with the actual horizon. The disoriented pilot may place the aircraft in a dangerous attitude.

Autokinesis

In the dark, a stationary light will appear to move about when stared at for many seconds. The disoriented pilot could lose control of the aircraft in attempting to align it with the false movements of this light, called autokinesis.

Postural Considerations

The postural system sends signals from the skin, joints, and muscles to the brain that are interpreted in relation to the Earth's gravitational pull. These signals determine posture. Inputs from each movement update the body's position to the brain on a constant basis. "Seat of the pants" flying is largely dependent upon these signals. Used in conjunction with visual and vestibular clues, these sensations can be fairly reliable. However, because of the forces acting upon the body in certain flight situations, many false sensations can occur due to acceleration forces overpowering gravity. *[Figure 1-8]* These situations include uncoordinated turns, climbing turns, and turbulence.

Demonstration of Spatial Disorientation

There are a number of controlled aircraft maneuvers a pilot can perform to experiment with spatial disorientation. While each maneuver will normally create a specific illusion, any false sensation is an effective demonstration of disorientation. Thus, even if there is no sensation during any of these maneuvers, the absence of sensation is still an effective demonstration in that it shows the inability to detect bank or roll. There are several objectives in demonstrating these various maneuvers.

1. They teach pilots to understand the susceptibility of the human system to spatial disorientation.
2. They demonstrate that judgments of aircraft attitude based on bodily sensations are frequently false.
3. They help lessen the occurrence and degree of disorientation through a better understanding of the relationship between aircraft motion, head movements, and resulting disorientation.
4. They help instill a greater confidence in relying on flight instruments for assessing true aircraft attitude.

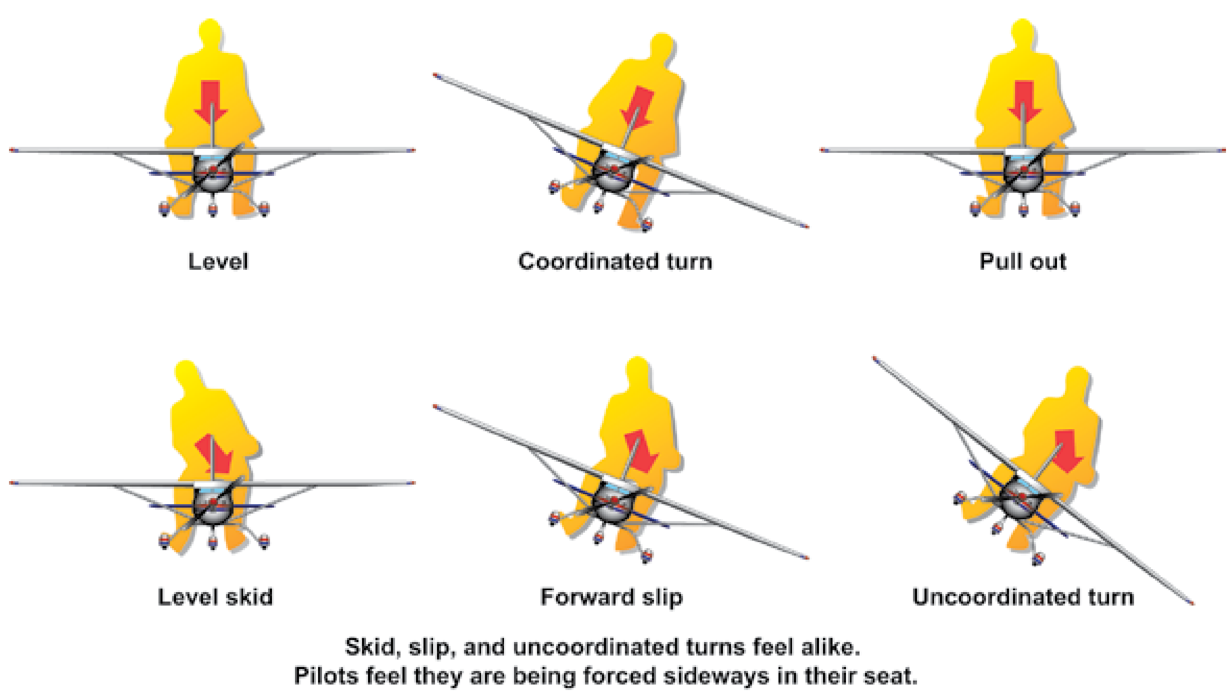

Figure 1-8. *Sensations From Centrifugal Force.*

A pilot should not attempt any of these maneuvers at low altitudes, or in the absence of an instructor pilot or an appropriate safety pilot.

Climbing While Accelerating

With the pilot's eyes closed, the instructor pilot maintains approach airspeed in a straight-and-level attitude for several seconds, and then accelerates while maintaining straight-and-level attitude. The usual illusion during this maneuver, without visual references, will be that the aircraft is climbing.

Climbing While Turning

With the pilot's eyes still closed and the aircraft in a straight-and-level attitude, the instructor pilot now executes, with a relatively slow entry, a well-coordinated turn of about 1.5 positive G (approximately 50° bank) for 90°. While in the turn, without outside visual references and under the effect of the slight positive G, the usual illusion produced is that of a climb. Upon sensing the climb, the pilot should immediately open the eyes and see that a slowly established, coordinated turn produces the same feeling as a climb.

Diving While Turning

Repeating the previous procedure, with the exception that the pilot's eyes should be kept closed until recovery from the turn is approximately one-half completed can create this sensation. With the eyes closed, the usual illusion will be that the aircraft is diving.

Tilting to Right or Left

While in a straight-and-level attitude, with the pilot's eyes closed, the instructor pilot executes a moderate or slight skid to the left with wings level. This creates the illusion of the body being tilted to the right.

Reversal of Motion

This illusion can be demonstrated in any of the three planes of motion. While straight and level, with the pilot's eyes closed, the instructor pilot smoothly and positively rolls the aircraft to approximately a 45° bank attitude while maintaining heading and pitch attitude. This creates the illusion of a strong sense of rotation in the opposite direction. After this illusion is noted, the pilot should open his or her eyes and observe that the aircraft is in a banked attitude.

Diving or Rolling Beyond the Vertical Plane

This maneuver may produce extreme disorientation. While in straight-and-level flight, the pilot should sit normally, either with eyes closed or gaze lowered to the floor. The instructor pilot starts a positive, coordinated roll toward a 30° or 40° angle of bank. As this is in progress, the pilot tilts his or her head forward, looks to the right or left, then immediately returns his or her head to an upright position. The instructor pilot should time the maneuver so the roll is stopped as the pilot returns his or her head upright. An intense disorientation is usually produced by this maneuver, and the pilot experiences the sensation of falling downward into the direction of the roll.

In the descriptions of these maneuvers, the instructor pilot is doing the flying, but having the pilot do the flying can also be a very effective demonstration. The pilot should close his or her eyes and tilt the head to one side. The instructor pilot tells the pilot what control inputs to perform. The pilot then attempts to establish the correct attitude or control input with eyes closed and head tilted. While it is clear the pilot has no idea of the actual attitude, he or she will react to what the senses are saying. After a short time, the pilot will become disoriented and the instructor pilot then tells the pilot to look up and recover. The benefit of this exercise is the pilot experiences the disorientation while flying the aircraft.

Coping with Spatial Disorientation

To prevent illusions and their potentially disastrous consequences, pilots can:

1. Understand the causes of these illusions and remain constantly alert for them. Take the opportunity to understand and then experience spatial disorientation illusions in a device such as a Barany chair, a Vertigon, or a Virtual Reality Spatial Disorientation Demonstrator.
2. Always obtain and understand preflight weather briefings.
3. Before flying in marginal visibility (less than 3 miles) or where a visible horizon is not evident such as flight over open water during the night, obtain training and maintain proficiency in airplane control by reference to instruments.
4. Do not continue flight into adverse weather conditions or into dusk or darkness unless proficient in the use of flight instruments. If intending to fly at night, maintain night-flight currency and proficiency. Include cross-country and local operations at various airfields.
5. Ensure that when outside visual references are used, they are reliable, fixed points on the Earth's surface.
6. Avoid sudden head movement, particularly during takeoffs, turns, and approaches to landing.
7. Be physically tuned for flight into reduced visibility. That is, ensure proper rest, adequate diet, and, if flying at night, allow for night adaptation. Remember that illness, medication, alcohol, fatigue, sleep loss, and mild hypoxia are likely to increase susceptibility to spatial disorientation.

8. Most importantly, become proficient in the use of flight instruments and rely upon them. Trust the instruments and disregard your sensory perceptions.

The sensations that lead to illusions during instrument flight conditions are normal perceptions experienced by pilots. These undesirable sensations cannot be completely prevented, but through training and awareness, pilots can ignore or suppress them by developing absolute reliance on the flight instruments. As pilots gain proficiency in instrument flying, they become less susceptible to these illusions and their effects.

Optical Illusions

Of the senses, vision is the most important for safe flight. However, various terrain features and atmospheric conditions can create optical illusions. These illusions are primarily associated with landing. Since pilots must transition from reliance on instruments to visual cues outside the flight deck for landing at the end of an instrument approach, it is imperative they be aware of the potential problems associated with these illusions, and take appropriate corrective action. The major illusions leading to landing errors are described below.

Runway Width Illusion

A narrower-than-usual runway can create an illusion the aircraft is at a higher altitude than it actually is, especially when runway length-to-width relationships are comparable. *[Figure 1-9A]* The pilot who does not recognize this illusion will fly a lower approach, with the risk of striking objects along the approach path or landing short. A wider-than-usual runway can have the opposite effect, with the risk of leveling out high and landing hard, or overshooting the runway.

Runway and Terrain Slopes Illusion

An upsloping runway, upsloping terrain, or both, can create an illusion the aircraft is at a higher altitude than it actually is. *[Figure 1-9B]* The pilot who does not recognize this illusion will fly a lower approach. Downsloping runways and downsloping approach terrain can have the opposite effect.

Featureless Terrain Illusion

An absence of surrounding ground features, as in an overwater approach, over darkened areas, or terrain made featureless by snow, can create an illusion the aircraft is at a higher altitude than it actually is. This illusion, sometimes referred to as the "black hole approach," causes pilots to fly a lower approach than is desired.

Water Refraction

Rain on the windscreen can create an illusion of being at a higher altitude due to the horizon appearing lower than it is. This can result in the pilot flying a lower approach.

Haze

Atmospheric haze can create an illusion of being at a greater distance and height from the runway. As a result, the pilot will have a tendency to be low on the approach. Conversely, extremely clear air (clear bright conditions of a high attitude airport) can give the pilot the illusion of being closer than he or she actually is, resulting in a high approach, which may result in an overshoot or go around. The diffusion of light due to water particles on the windshield can adversely affect depth perception. The lights and terrain features normally used to gauge height during landing become less effective for the pilot.

Fog

Flying into fog can create an illusion of pitching up. Pilots who do not recognize this illusion will often steepen the approach quite abruptly.

Ground Lighting Illusions

Lights along a straight path, such as a road or lights on moving trains, can be mistaken for runway and approach lights. Bright runway and approach lighting systems, especially where few lights illuminate the surrounding terrain, may create the illusion of less distance to the runway. The pilot who does not recognize this illusion will often fly a higher approach.

How To Prevent Landing Errors Due to Optical Illusions

To prevent these illusions and their potentially hazardous consequences, pilots can:

1. Anticipate the possibility of visual illusions during approaches to unfamiliar airports, particularly at night or in adverse weather conditions. Consult airport diagrams and the Airport/Facility Directory (A/FD) for information on runway slope, terrain, and lighting.
2. Make frequent reference to the altimeter, especially during all approaches, day and night.
3. If possible, conduct aerial visual inspection of unfamiliar airports before landing.

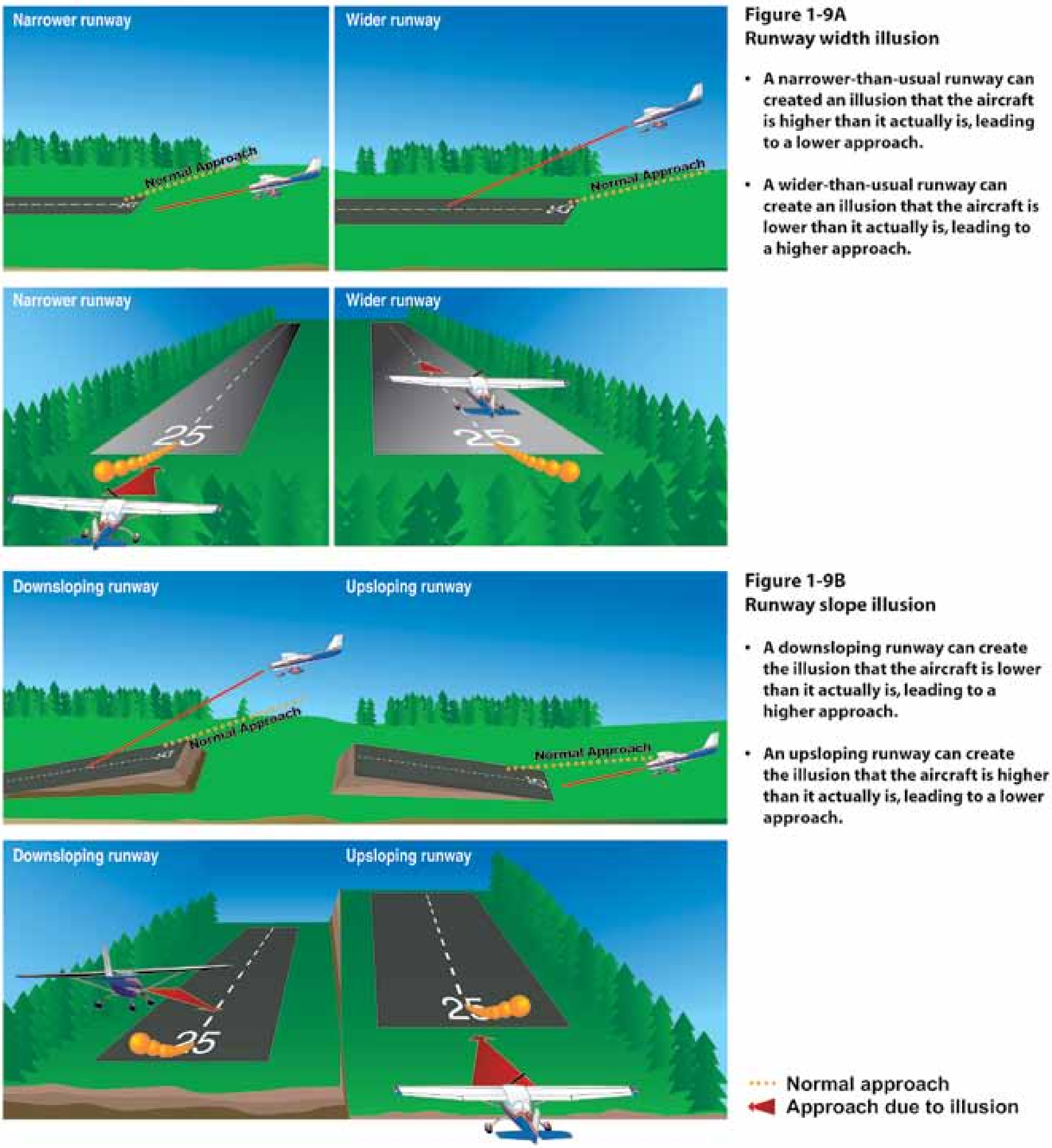

Figure 1-9. *Runway Width and Slope Illusions.*

4. Use Visual Approach Slope Indicator (VASI) or Precision Approach Path Indicator (PAPI) systems for a visual reference, or an electronic glide slope, whenever they are available.
5. Utilize the visual descent point (VDP) found on many nonprecision instrument approach procedure charts.
6. Recognize that the chances of being involved in an approach accident increase when some emergency or other activity distracts from usual procedures.
7. Maintain optimum proficiency in landing procedures.

Physiological and Psychological Factors

Physiological or psychological factors can affect a pilot and compromise the safety of a flight. These factors are stress, medical, alcohol, and fatigue. Any of these factors, individually or in combination, significantly degrade the pilot's decision-making or flying abilities.

Stress

Stress is the body's response to demands placed upon it. These demands can be either pleasant or unpleasant in nature. The causes of stress for a pilot can range from unexpected weather or mechanical problems while in flight, to personal issues unrelated to flying. Stress is an inevitable and necessary part of life; it adds motivation to life and heightens an individual's response to meet any challenge. The effects of stress are cumulative and there is a limit to a person's adaptive nature. This limit, called the stress tolerance level (or channel capacity), is based on the ability to cope with the situation.

At first, some amount of stress can be desirable and can actually improve performance. However, higher stress levels, particularly over long periods of time, can adversely affect performance. Performance will generally increase with the onset of stress, but will peak and then begin to fall off rapidly as stress levels exceed the ability to cope. *[Figure 1-10]*

At this point, a pilot's performance begins to decline and judgment deteriorates. Complex or unfamiliar tasks require higher levels of performance than simple or overlearned tasks. Complex or unfamiliar tasks are also more subject to the adverse effects of increasing stress than simple or familiar tasks. *[Figure 1-10]*

The indicators of excessive stress often show as three types of symptoms: (1) emotional, (2) physical, and (3) behavioral. Emotional symptoms may surface as over-compensation, denial, suspicion, paranoia, agitation, restlessness, or defensiveness. Physical stress can result in acute fatigue while behavioral degradation will be manifested as sensitivity to criticism, tendency to be argumentative, arrogance, and hostility. Pilots need to learn to recognize the symptoms of stress as they begin to occur.

There are many techniques available that can help reduce stress in life or help people cope with it better. Not all of the following ideas may be a solution, but some of them should be effective.

1. Become knowledgeable about stress.
2. Take a realistic self-assessment. (See the Pilot's Handbook of Aeronautical Knowledge).
3. Take a systematic approach to problem solving.
4. Develop a lifestyle that will buffer against the effects of stress.
5. Practice behavior management techniques.
6. Establish and maintain a strong support network.

Good flight deck stress management begins with good life stress management. Many of the stress coping techniques practiced for life stress management are not usually practical in flight. Rather, pilots must condition themselves to relax and think rationally when stress appears. The following checklist outlines some methods of flight deck stress management.

1. Avoid situations that distract from flying the aircraft.
2. Reduce flight deck workload to reduce stress levels. This will create a proper environment in which to make good decisions. Typically, flying involves higher stress levels during takeoff and landing phases. Between the two generally lies a period of low activity resulting in a lower stress level. Transitioning from the cruise phase to the landing phase is generally accompanied by a significant workload that, if not properly accommodated, will increase stress significantly. Proper planning and prioritization of flight deck duties are key to avoiding events that affect the pilot's capacity to maintain situational awareness.

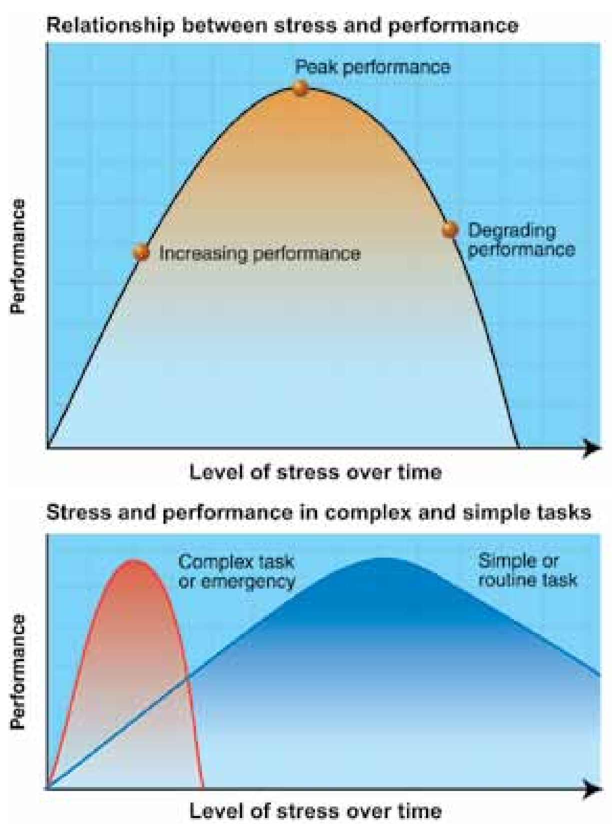

Figure 1-10. *Stress and Performance.*

3. If a problem occurs, remain calm. If time is not a pressing factor, follow the analytical approach to decision-making: think for a moment, weigh the alternatives, select and take an appropriate course of action, and then evaluate its effects.

   If an emergency situation occurs, remain calm and use the aeronautical decision-making (ADM) process to resolve the emergency. This process relies on the pilot's training and experience to accurately and automatically respond to an emergency situation. Constant training in handling emergency procedures will help reduce pilot stress when an emergency occurs.

4. Become thoroughly familiar with the aircraft, its operation, and emergency procedures. Also, maintain flight proficiency to build confidence.

5. Know and respect personal limits. Studies have suggested that highly experienced pilots have taken more chances when flying into potential icing conditions than low time or inexperienced pilots. Very low time pilots without experience may analyze and interpret the likelihood for "potential" flight into icing without the benefit of life experience, thereby making decisions closely aligned with the compilation of their training and recent academic knowledge. Highly experienced pilots may evaluate the current situation based upon the empirical information (sometimes diluted with time) coupled with their vast experience. This may lead to a level of greater acceptability of the situation because their experience has illustrated successful navigation of this problem before. Therefore, the automatic decision may be in error because not all salient facts are evaluated.

6. Do not allow small mistakes to be distractions during flight; rather, review and analyze them after landing.

7. If flying adds stress, either stop flying or seek professional help to manage stress within acceptable limits.

Medical Factors

A "go/no-go" decision based on a pilot's medical factors is made before each flight. The pilot should not only preflight check the aircraft, but also himself or herself before every flight. A pilot should ask, "Can I pass my medical examination right now?" If the answer is not an absolute "yes," *do not fly*. This is especially true for pilots embarking on flights in IMC. Instrument flying is much more demanding than flying in VMC, and peak performance is critical for the safety of flight.

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

Title 14 of the Code of Federal Regulations (14 CFR) prohibits pilots from performing crewmember duties while using any medication that affects the faculties in any way contrary to safety. The safest rule is not to fly as a crewmember while taking any medication, unless approved to do so by the Federal Aviation Administration (FAA). If there is any doubt regarding the effects of any medication, consult an Aviation Medical Examiner (AME) before flying.

Alcohol

14 CFR part 91 prohibits pilots from performing crewmember duties within 8 hours after drinking any alcoholic beverage or while under the influence. Extensive research has provided a number of facts about the hazards of alcohol consumption and flying. As little as one ounce of liquor, one bottle of beer, or four ounces of wine can impair flying skills and render a pilot much more susceptible to disorientation and hypoxia. Even after the body completely metabolizes a moderate amount of alcohol, a pilot can still be impaired for many hours. There is simply no way of increasing the metabolism of alcohol or alleviating a hangover.

Fatigue

Fatigue is one of the most treacherous hazards to flight safety, as it may not be apparent to a pilot until serious errors are made. Fatigue can be either acute (short-term) or chronic (long-term).

Acute Fatigue

A normal occurrence of everyday living, acute fatigue is the tiredness felt after long periods of physical and mental strain, including strenuous muscular effort, immobility, heavy mental workload, strong emotional pressure, monotony, and lack of sleep. Adequate rest, regular exercise, and proper nutrition prevent acute fatigue.

Indications of fatigue are generally subtle and hard to recognize because the individual being assessed is generally the person making the assessment, as in single pilot operations. Therefore, the pilot must look at small errors that occur to provide an indication of becoming fatigued. These include:

- Misplacing items during the preflight;
- Leaving material (pencils, charts) in the planning area;
- Missing radio calls;
- Answering calls improperly (read-backs); and
- Improper tuning of frequencies.

Chronic Fatigue

Chronic fatigue occurs when there is not enough time for a full recovery from repeated episodes of acute fatigue. Chronic fatigue's underlying cause is generally not "rest-related" and may have deeper points of origin. Therefore, rest alone may not resolve chronic fatigue.

Chronic fatigue is a combination of both physiological problems and psychological issues. Psychological problems such as financial, home life, or job related stresses cause a lack of qualified rest that is only resolved by mitigating the underpinning problems. Without resolution, performance continues to fall off, judgment becomes impaired, and unwarranted risks are taken. Recovery from chronic fatigue requires a prolonged and deliberate solution. In either case, unless adequate precautions are taken, personal performance could be impaired and adversely affect pilot judgment and decision-making.

IMSAFE Checklist

The following checklist, IMSAFE, is intended for a pilot's personal preflight use. A quick check of the items on this list will help a pilot make a good self-evaluation prior to any flight. If the answer to any of the checklist questions is yes, then the pilot should consider not flying.

Illness
Do I have any symptoms?

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

Stress
Am I under psychological pressure from the job? Do I have money, health, or family problems?

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

Fatigue
Am I tired and not adequately rested?

Eating
Have I eaten enough of the proper foods to keep adequately nourished during the entire flight?

Hazard Identification

In order to identify a hazard, it would be useful to define what a hazard is. The FAA System Safety course defines a hazard as: "a present condition, event, object, or circumstance that could lead or contribute to an unplanned or undesired event." Put simply, a hazard is a source of danger. Potential hazards may be identified from a number of internal and external sources. These may be based upon several concurrent factors that provide an indication and ultimate identification of a hazard. Consider the following situations:

Situation 1

The pilot has just taken off and is entering the clouds. Suddenly, there is an explosive sound. The sudden noise is disturbing and occurs as the pilot is given a new heading, a climb restriction, and the frequency for the departure control.

Situation 2

The pilot took off late in a rented aircraft (first time flying this model), and is now in night conditions due to the delay, and flying on an instrument flight rules (IFR) flight plan in IMC conditions. The radios do not seem to work well and develop static. They seem to be getting weaker. As the pilot proceeds, the rotating beacon stops flashing/rotating, and the lights become dimmer. As the situation progresses, the pilot is unaware of the problem because the generator warning light, (on the lower left of the panel) is obscured by the chart on the pilot's lap.

Both situations above represent hazards that must be dealt with differently and a level of risk must be associated with each depending on various factors affecting the flight.

Risk Analysis

Risk is defined as the future impact of a hazard that is not eliminated or controlled. It is the possibility of loss or injury. Risk analysis is the process whereby hazards are characterized by their likelihood and severity. Risk analysis evaluates the hazards to determine the outcomes and how abrupt that outcome will occur. The analysis applied will be qualitative to the degree that time allows resulting in either an analytical or automatic approach in the decision-making process.

In the first situation, the decision may be automatic: fly the airplane to a safe landing. Since automatic decision-making is based upon education and experience, an inexperienced pilot may react improperly to the situation which results in an inadequate action. To mitigate improper decision-making, immediate action items from emergency procedures should be learned. Training, education, and mentorship are all key factors in honing automatic decision-making skills.

In the second situation, if the pilot has a flashlight onboard, it can be used for illumination, although its light may degrade night vision. After changing the appropriate transponder code, and making calls in the blind, awareness of present location becomes imperative, especially if the pilot must execute a controlled descent to VMC conditions. Proper preflight planning conducted before departure and constant awareness of location provide an element of both comfort (reduces stress) and information from which the pilot can draw credible information.

In both cases, the outcomes can be successful through systems understanding, emergency procedures training, and correctly analyzing the risks associated with each course of action.

Crew Resource Management (CRM) and Single-Pilot Resource Management (SRM)

Crew resource management (CRM) and single-pilot resource management (SRM) is the ability for the crew or pilot to manage all resources effectively to ensure the outcome of the flight is successful. In general aviation, SRM will be most often used and its focus is on the single-pilot operation. SRM integrates the following:

- Situational Awareness
- Flight Deck Resource Management
- Task Management
- Aeronautical Decision-making (ADM) and Risk Management

SRM recognizes the need to seek proper information from these sources to make a valid decision. For instance, the pilot may have to request assistance from others and be assertive to resolve situations. Pilots should understand the need to seek information from other sources until they have the proper information to make the best decision. Once a pilot has gathered all pertinent information and made the appropriate decision, the pilot needs to perform an assessment of the action taken.

Situational Awareness

Situational awareness is the accurate perception of operational and environmental factors that affect the flight. It is a logical analysis based upon the machine, external support, environment, and the pilot. It is knowing what is going on.

Flight Deck Resource Management

CRM is the effective use of all available resources: human, equipment, and information. It focuses on communication skills, teamwork, task allocation, and decision-making. While CRM often concentrates on pilots who operate in crew environments, the elements and concepts also apply to single-pilot operations.

Human Resources

Human resources include everyone routinely working with the pilot to ensure flight safety. These people include, but are not limited to: weather briefers, flight line personnel, maintenance personnel, crew members, pilots, and air traffic personnel. Pilots need to effectively communicate with these people. This is accomplished by using the key components of the communication process: inquiry, advocacy, and assertion.

Pilots must recognize the need to seek enough information from these resources to make a valid decision. After the necessary information has been gathered, the pilot's decision must be passed on to those concerned, such as air traffic controllers, crew members, and passengers. The pilot may have to request assistance from others and be assertive to safely resolve some situations.

Equipment

Equipment in many of today's aircraft includes automated flight and navigation systems. These automatic systems, while providing relief from many routine flight deck tasks, present a different set of problems for pilots. The automation intended to reduce pilot workload essentially removes the pilot from the process of managing the aircraft, thereby reducing situational awareness and leading to complacency. Information from these systems needs to be continually monitored to ensure proper situational awareness. Pilots should be thoroughly familiar with the operation of and information provided by all systems used. It is essential that pilots be aware not only of equipment capabilities, but also equipment limitations in order to manage those systems effectively and safely.

Information Workload

Information workloads and automated systems, such as autopilots, need to be properly managed to ensure a safe flight. The pilot flying in IMC is faced with many tasks, each with a different level of importance to the outcome of the flight. For example, a pilot preparing to execute an instrument approach to an airport needs to review the approach chart, prepare the aircraft for the approach and landing, complete checklists, obtain information from Automatic Terminal Information Service (ATIS) or air traffic control (ATC), and set the navigation radios and equipment.

The pilot who effectively manages his or her workload will complete as many of these tasks as early as possible to preclude the possibility of becoming overloaded by last minute changes and communication priorities in the later, more critical stages of the approach. *Figure 1-11* shows the margin of safety is at the minimum level during this stage of the approach. Routine tasks delayed until the last minute can contribute to the pilot becoming overloaded and stressed, resulting in erosion of performance.

By planning ahead, a pilot can effectively reduce workload during critical phases of flight. If a pilot enters the final phases of the instrument approach unprepared, the pilot should recognize the situation, abandon the approach, and try it again after becoming better prepared. Effective resource management includes recognizing hazardous situations and attitudes, decision-making to promote good judgment and headwork, and managing the situation to ensure the safe outcome of the IFR flight.

Task Management

Pilots have a limited capacity for information. Once information flow exceeds the pilot's ability to mentally process the information any additional information will become unattended or displace other tasks and information already being processed. This is termed channel capacity and once reached only two alternatives exist: shed the unimportant tasks or perform all tasks at a less than optimal level. Like an electrical circuit being overloaded, either the consumption must be reduced or a circuit failure is experienced.

The pilot who effectively manages the tasks and properly prioritizes them will have a successful flight. For example, do not become distracted and fixate on an instrument light failure. This unnecessary focus displaces capability and prevents the pilot's ability to appreciate tasks of greater importance. By planning ahead, a pilot can effectively reduce workload during critical phases of a flight.

Aeronautical Decision-Making (ADM)

Flying safely requires the effective integration of three separate sets of skills. Most obvious are the basic stick-and-rudder skills needed to control the airplane. Next, are skills related to proficient operation of aircraft systems, and last, but not least, are ADM skills.

ADM is a systematic approach to the mental process used by pilots to consistently determine the best course of action in response to a given set of circumstances. The importance of learning effective ADM skills cannot be overemphasized. While progress is continually being made in the advancement of pilot training methods, airplane equipment and systems, and services for pilots, accidents still occur. Despite all the changes in technology to improve flight safety, one factor remains the same—the human factor. While the FAA strives to eliminate errors through training and safety programs, one fact remains: humans make errors. It is estimated that approximately 80 percent of all aviation accidents are human factors related.

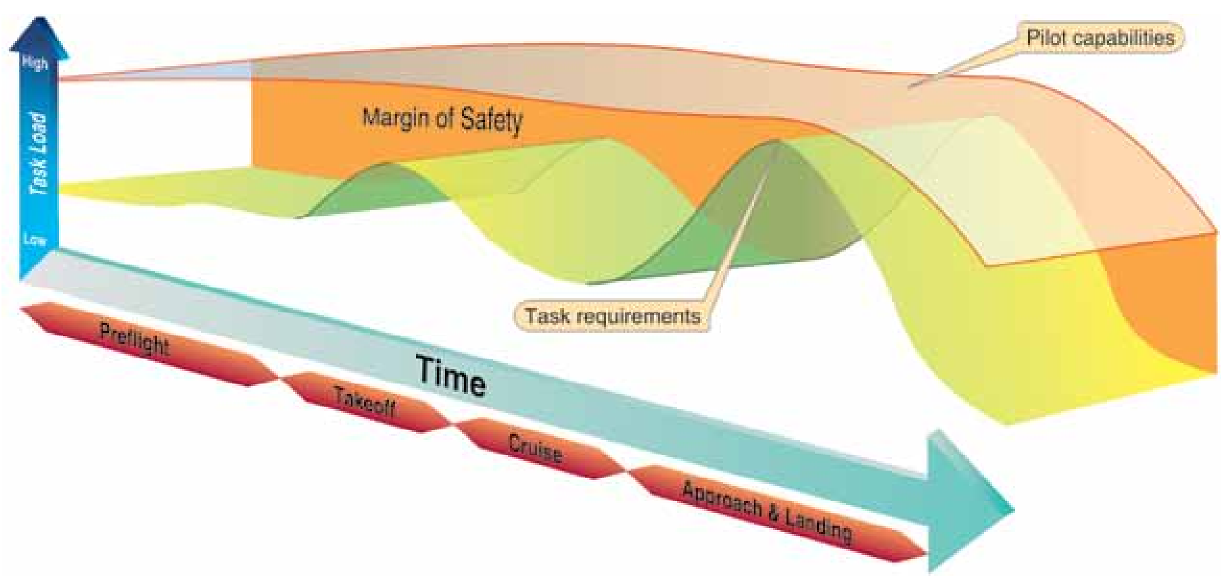

Figure 1-11. *The Margin of Safety.*

The ADM process addresses all aspects of decision making in the flight deck and identifies the steps involved in good decision making. While the ADM process will not eliminate errors, it will help the pilot recognize errors, and in turn enable the pilot to manage the error to minimize its effects. These steps are:

1. Identifying personal attitudes hazardous to safe flight;
2. Learning behavior modification techniques;
3. Learning how to recognize and cope with stress;
4. Developing risk assessment skills;
5. Using all resources; and
6. Evaluating the effectiveness of one's ADM skills.

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

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

The Decision-Making Process

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

Defining the Problem

Problem definition is the first step in the decision-making process. Defining the problem begins with recognizing that a change has occurred or that an expected change did not occur. A problem is perceived first by the senses, then is distinguished through insight and experience. One critical error that can be made during the decision-making process is incorrectly defining the problem. For example, a low oil pressure reading could indicate that the engine is about to fail and an emergency landing should be planned, or it could mean that the oil pressure sensor has failed. The actions to be taken in each of these circumstances would be significantly different. One requires an immediate decision based upon training, experience, and evaluation of the situation; whereas the latter decision is based upon an analysis. It should be noted that the same indication could result in two different actions depending upon other influences.

Choosing a Course of Action

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

Implementing the Decision and Evaluating the Outcome

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

Improper Decision-Making Outcomes

Pilots sometimes get in trouble not because of deficient basic skills or system knowledge, but rather because of faulty decision-making skills. Although aeronautical decisions may appear to be simple or routine, each individual decision in aviation often defines the options available for the next decision the pilot must make and the options, good or bad, they provide. Therefore, a poor decision early on in a flight can compromise the safety of the flight at a later time necessitating decisions that must be more accurate and decisive. Conversely, good decision-making early on in an emergency provide greater latitude for options later on.

FAA Advisory Circular (AC) 60-22, defines ADM as a systematic approach to the mental process of evaluating a given set of circumstances and determining the best course of action. ADM thus builds upon the foundation of conventional decision-making, but enhances the process to decrease the probability of pilot error. Specifically, ADM provides a structure to help the pilot use all resources to develop comprehensive situational awareness.

Models for Practicing ADM

Two models for practicing ADM are presented below.

Perceive, Process, Perform

The Perceive–Process–Perform (3P) model for ADM offers a simple, practical, and systematic approach that can be used during all phases of flight. *[Figure 1-12]* To use it, the pilot will:

- Perceive the given set of circumstances for a flight;
- Process by evaluating their impact on flight safety; and
- Perform by implementing the best course of action.

Figure 1-12. *The 3P Model for Aeronautical Decision-Making.*

In the first step, the goal is to develop situational awareness by perceiving hazards, which are present events, objects, or circumstances that could contribute to an undesired future event. In this step, the pilot will systematically identify and list hazards associated with all aspects of the flight: pilot, aircraft, environment, and external pressures. It is important to consider how individual hazards might combine. Consider, for example, the hazard that arises when a new instrument pilot with no experience in actual instrument conditions wants to make a cross-country flight to an airport with low ceilings in order to attend an important business meeting.

In the second step, the goal is to process this information to determine whether the identified hazards constitute risk, which is defined as the future impact of a hazard that is not controlled or eliminated. The degree of risk posed by a given hazard can be measured in terms of exposure (number of people or resources affected), severity (extent of possible loss), and probability (the likelihood that a hazard will cause a loss). If the hazard is low ceilings, for example, the level of risk depends on a number of other factors, such as pilot training and experience, aircraft equipment and fuel capacity, and others.

In the third step, the goal is to perform by taking action to eliminate hazards or mitigate risk, and then continuously evaluate the outcome of this action. With the example of low ceilings at destination, for instance, the pilot can perform good ADM by selecting a suitable alternate, knowing where to find good weather, and carrying sufficient fuel to reach it. This course of action would mitigate the risk. The pilot also has the option to eliminate it entirely by waiting for better weather.

Once the pilot has completed the 3P decision process and selected a course of action, the process begins anew because now the set of circumstances brought about by the course of action requires analysis. The decision-making process is a continuous loop of perceiving, processing and performing.

The DECIDE Model

Another structured approach to ADM is the DECIDE model, which is a six-step process intended to provide a logical way of approaching decision-making. As in the 3P model, the elements of the DECIDE model represent a continuous loop process to assist a pilot in the decision-making required when faced with a situational change that requires judgment. *[Figure 1-13C]* The model is primarily focused on the intellectual component, but can have an impact on the motivational component of judgment as well. If a pilot continually uses the DECIDE Model in all decision-making, it becomes natural and results in better decisions being made under all types of situations. The steps in this approach are listed in *Figure 1-13C*.

In conventional decision-making, the need for a decision is triggered by recognition that something has changed or an expected change did not occur. Recognition of the change, or lack of change, is a vital step in any decision making process. Not noticing change in a situation can lead directly to a mishap. *[Figure 1-13A]* The change indicates that an appropriate response or action is necessary in order to modify the situation (or, at least, one of the elements that comprise it) and bring about a desired new situation. Therefore, situational awareness is the key to successful and safe decision making. At this point in the process, the pilot is faced with a need to evaluate the entire range of possible responses to the detected change and to determine the best course of action.

Figure 1-13B illustrates how the ADM process expands conventional decision-making, shows the interactions of the

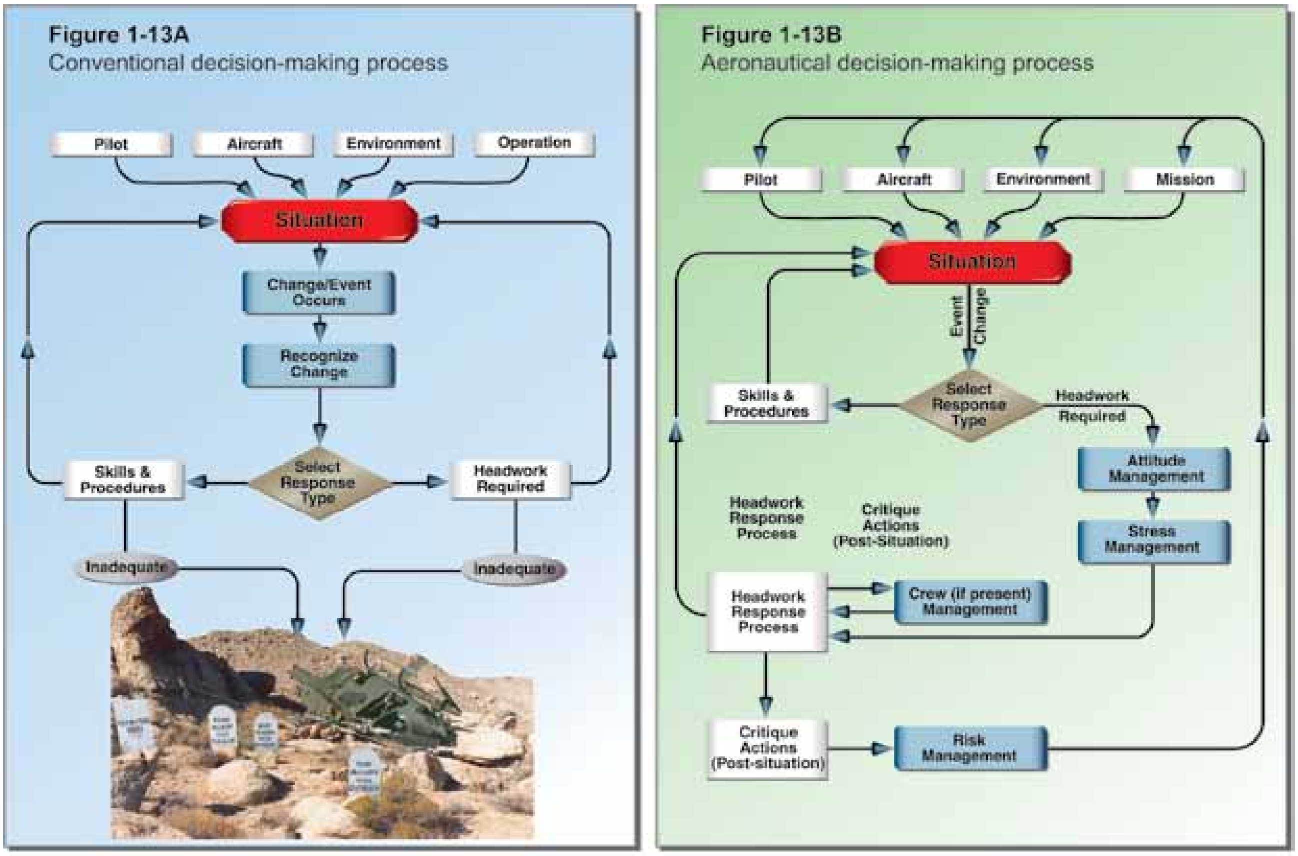

Figure 1-13C
The DECIDE Model

1. **Detect.** The decision maker detects the fact that change has occurred.
2. **Estimate.** The decision maker estimates the need to counter or react to the change.
3. **Choose.** The decision maker chooses a desirable outcome (in terms of success) for the flight.
4. **Identify.** The decision maker identifies actions which could successfully control the change.
5. **Do.** The decision maker takes the necessary action.
6. **Evaluate.** The decision maker evaluates the effect(s) of his/her action countering the change.

Figure 1-13. *Decision-Making.*

ADM steps, and how these steps can produce a safe outcome. Starting with the recognition of change, and following with an assessment of alternatives, a decision to act or not act is made, and the results are monitored. Pilots can use ADM to enhance their conventional decision-making process because it:

1. Increases their awareness of the importance of attitude in decision-making;
2. Teaches the ability to search for and establish relevance of information; and
3. Increases their motivation to choose and execute actions that ensure safety in the situational timeframe.

Hazardous Attitudes and Antidotes

Hazardous attitudes, which contribute to poor pilot judgment, can be effectively counteracted by redirecting that hazardous attitude so that correct action can be taken. Recognition of hazardous thoughts is the first step toward neutralizing them. After recognizing a thought as hazardous, the pilot should label it as hazardous, then state the corresponding antidote. Antidotes should be memorized for each of the hazardous attitudes so they automatically come to mind when needed. Each hazardous attitude along with its appropriate antidote is shown in *Figure 1-14*.

Hazardous Attitude	Antidote
Anti-authority: Don't tell me.	Follow the rules. They are usually right.
Impulsivity: Do something quicky.	Not so fast. Think first.
Invulnerability: It won't happen to me.	It could happen to me.
Macho: I can do it.	Taking chances is foolish.
Resignation: What's the use?	I'm not helpless. I can make a difference.

Figure 1-14. *The Five Antidotes to Hazardous Attitudes.*

Research has identified five hazardous attitudes that can affect a pilot's judgment, as well as antidotes for each of these five attitudes. ADM addresses the following:

1. Anti-authority ("Don't tell me!"). This attitude is found in pilots who do not like anyone telling them what to do. They may be resentful of having someone tell them what to do or may regard rules, regulations, and procedures as silly or unnecessary. However, there is always the prerogative to question authority if it is perceived to be in error.
2. Impulsivity ("Do something quickly!"). This attitude is found in pilots who frequently feel the need to do something—anything—immediately. They do not stop to think about what they are about to do, they do not select the best course of action, and they do the first thing that comes to mind.
3. Invulnerability ("It won't happen to me!"). Many pilots feel that accidents happen to others, but never to them. They know accidents can happen, and they know that anyone can be affected. They never really feel or believe that they will be personally involved. Pilots who think this way are more likely to take chances and increase risk.
4. Macho ("I can do it!"). Pilots who are always trying to prove that they are better than anyone else are thinking, "I can do it—I'll show them." Pilots with this type of attitude will try to prove themselves by taking risks in order to impress others. This pattern is characteristic in both men and women.
5. Resignation ("What's the use?"). These pilots do not see themselves as being able to make a great deal of difference in what happens to them. When things go well, these pilots are apt to think it is due to good luck. When things go badly, they may feel that someone is out to get them, or attribute it to bad luck. The pilot will leave the action to others, for better or worse. Sometimes, they will even go along with unreasonable requests just to be a "nice guy."