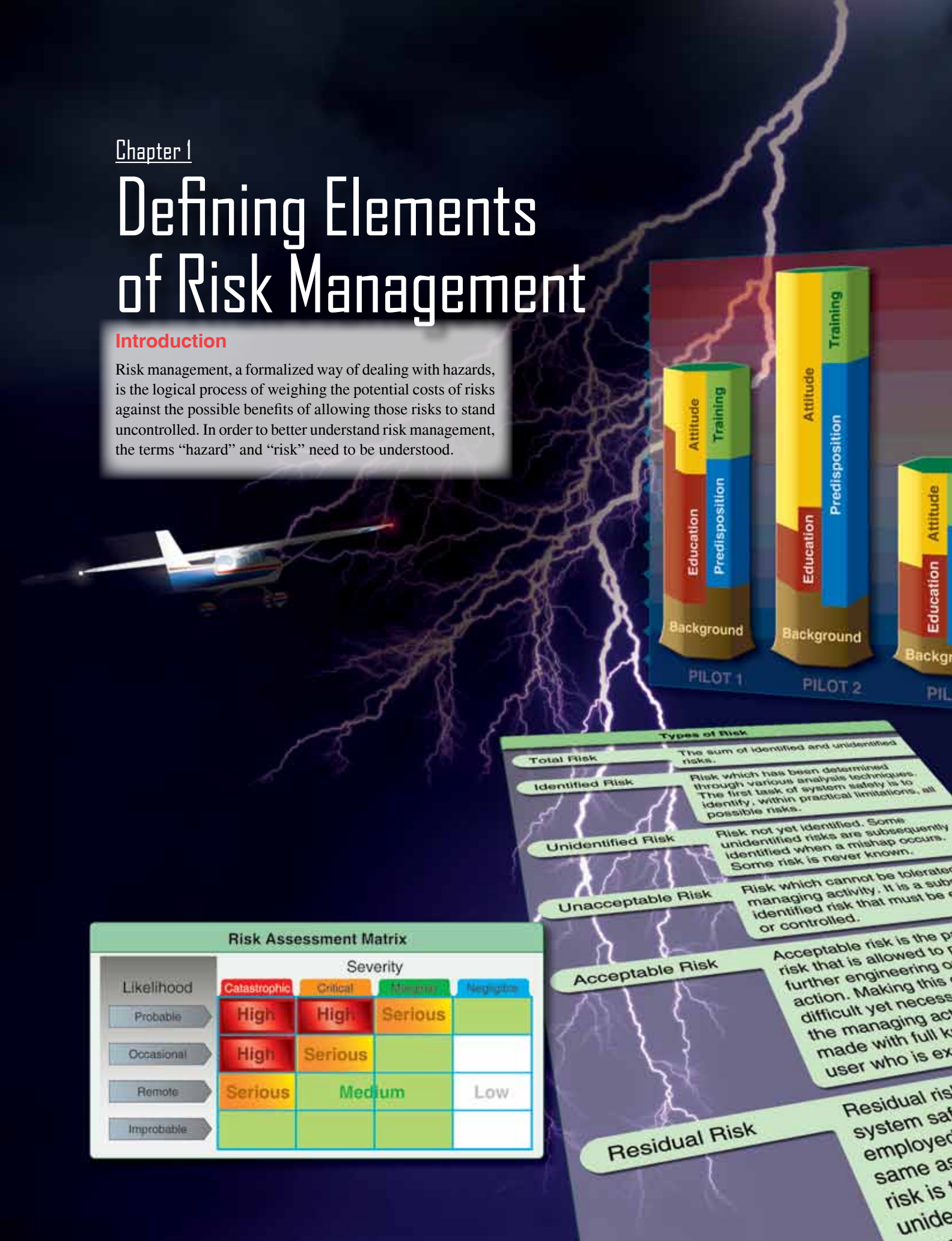
Chapter 1

Defining Elements of Risk Management

Introduction

Risk management, a formalized way of dealing with hazards, is the logical process of weighing the potential costs of risks against the possible benefits of allowing those risks to stand uncontrolled. In order to better understand risk management, the terms "hazard" and "risk" need to be understood.



Hazard

Defining Hazard

By definition, a hazard is a present condition, event, object, or circumstance that could lead to or contribute to an unplanned or undesired event such as an accident. It is a source of danger. Four common aviation hazards are:

1. A nick in the propeller blade
2. Improper refueling of an aircraft
3. Pilot fatigue
4. Use of unapproved hardware on aircraft

Recognizing the Hazard

Recognizing hazards is critical to beginning the risk management process. Sometimes, one should look past the immediate condition and project the progression of the condition. This ability to project the condition into the future comes from experience, training, and observation.

1. A nick in the propeller blade is a hazard because it can lead to a fatigue crack, resulting in the loss of the propeller outboard of that point. With enough loss, the vibration could be great enough to break the engine mounts and allow the engine to separate from the aircraft.
2. Improper refueling of an aircraft is a hazard because improperly bonding and/or grounding the aircraft creates static electricity that can spark a fire in the refueling vapors. Improper refueling could also mean fueling a gasoline fuel system with turbine fuel. Both of these examples show how a simple process can become expensive at best and deadly at worst.
3. Pilot fatigue is a hazard because the pilot may not realize he or she is too tired to fly until serious errors are made. Humans are very poor monitors of their own mental condition and level of fatigue. Fatigue can be as debilitating as drug usage, according to some studies.
4. Use of unapproved hardware on aircraft poses problems because aviation hardware is tested prior to its use on an aircraft for such general properties as hardness, brittleness, malleability, ductility, elasticity, toughness, density, fusibility, conductivity, and contraction and expansion.

If pilots do not recognize a hazard and choose to continue, the risk involved is not managed. However, no two pilots see hazards in exactly the same way, making prediction and standardization of hazards a challenge. So the question remains, how do pilots recognize hazards? The ability to recognize a hazard is predicated upon personality, education, and experience.

Personality

Personality can play a large part in the manner in which hazards are gauged. People who might be reckless in nature take this on board the flight deck. For instance, in an article in the August 25, 2006, issue of Commercial and Business Aviation entitled Accident Prone Pilots, Patrick R. Veillette, Ph.D., notes that research shows one of the primary characteristics exhibited by accident-prone pilots was their disdain toward rules. Similarly, other research by Susan Baker, Ph.D., and her team of statisticians at the Johns Hopkins School of Public Health, found a very high correlation between pilots with accidents on their flying records and safety violations on their driving records. The article brings forth the question of how likely is it that someone who drives with a disregard of the driving rules and regulations will then climb into an aircraft and become a role model pilot. The article goes on to hypothesize that, for professional pilots, the financial and career consequences of deviating from standard procedures can be disastrous but can serve as strong motivators for natural-born thrill seekers.

Improving the safety records of the thrill seeking type pilots may be achieved by better educating them about the reasons behind the regulations and the laws of physics, which cannot be broken. The FAA rules and regulations were developed to prevent accidents from occurring. Many rules and regulations have come from studying accidents; the respective reports are also used for training and accident prevention purposes.

Education

The adage that one cannot teach an old dog new tricks is simply false. In the mid-1970s, airlines started to employ Crew Resource Management (CRM) in the workplace (flight deck). The program helped crews recognize hazards and provided tools for them to eliminate the hazard or minimize its impact. Today, this same type of thinking has been integrated into Single-Pilot Resource Management (SRM) programs (see chapter 6).

Regulations

Regulations provide restrictions to actions and are written to produce outcomes that might not otherwise occur if the regulation were not written. They are written to reduce hazards by establishing a threshold for the hazard. An example might be something as simple as basic visual flight rules (VFR) weather minimums as presented in Title 14 of the Code of Federal Regulation (14 CFR) part 91, section 91.155, which lists cloud clearance in Class E airspace as 1,000 feet below, 500 feet above, and 2,000 feet horizontally with flight visibility as three statute miles. This regulation provides both an operational boundary and one that a pilot can use in helping to recognize a hazard. For instance, a VFR-only rated pilot faced with weather that is far below that of Class E airspace

would recognize that weather as hazardous, if for no other reason than because it falls below regulatory requirements.

Experience

Experience is the knowledge acquired over time and increases with time as it relates to association with aviation and an accumulation of experiences. Therefore, can inexperience be construed as a hazard? Inexperience is a hazard if an activity demands experience of a high skill set and the inexperienced pilot attempts that activity. An example of this would be a wealthy pilot who can afford to buy an advanced avionics aircraft, but lacks the experience needed to operate it safely. On the other hand a pilot's experience can provide a false sense of security, leading the pilot to ignore or fail to recognize a potential hazard.

Experience sometimes influences the way a pilot looks at an aviation hazard and how he or she explores its level of risk. Revisiting the four original examples:

1. **A nick in the propeller blade.** The pilot with limited experience in the field of aircraft maintenance may not realize the significance of the nick. Therefore, he or she may not recognize it as a hazard. For the more experienced pilot, the nick represents the potential of a serious risk. This pilot realizes the nick can create or be the origin of a crack. What happens if the crack propagates, causing the loss of the outboard section? The ensuing vibration and possible loss of the engine would be followed by an extreme out-of-balance condition resulting in the loss of flight control and a crash.
2. **Improper refueling of an aircraft.** Although pilots and servicing personnel should be well versed on the grounding and/or bonding precautions as well as the requirements for safe fueling, it is possible the inexperienced pilot may be influenced by haste and fail to take proper precautions. The more experienced pilot is aware of how easily static electricity can be generated and how the effects of fueling a gasoline fuel system with turbine fuel can create hazards at the refueling point.
3. **Pilot fatigue.** Since indications of fatigue are subtle and hard to recognize, it often goes unidentified by a pilot. The more experienced pilot may actually ignore signals of fatigue because he or she believes flight experience will compensate for the hazard. For example, a businessman/pilot plans to fly to a meeting and sets an 8 a.m. departure for himself. Preparations for the meeting keep him up until 2 a.m. the night before the flight. With only several hours of sleep, he arrives at the airport ready to fly because he fails to recognize his lack of sleep as a hazard. The fatigued pilot is an impaired pilot, and flying requires unimpaired judgment. To offset the risk of fatigue, every pilot should get plenty of rest and minimize stress before a flight. If problems prevent a good night's sleep, rethink the flight, and postpone it accordingly.
4. **Use of unapproved hardware on aircraft.** Manufacturers specify the type of hardware to use on an aircraft, including components. Using anything other than that which is specified or authorized by parts manufacturing authorization (PMA) is a hazard. There are several questions that a pilot should consider that further explain why unapproved hardware is a hazard. Will it corrode when in contact with materials in the airframe structure? Will it break because it is brittle? Is it manufactured under loose controls such that some bolts may not meet the specification? What is the quality control process at the manufacturing plant? Will the hardware deform excessively when torqued to the proper specification? Will it stay tight and fixed in place with the specified torque applied? Is it loose enough to allow too much movement in the structure? Are the dollars saved really worth the possible costs and liability? As soon as a person departs from the authorized design and parts list, then that person becomes an engineer and test pilot, because the structure is no longer what was considered to be safe and approved. Inexperienced as well as experienced pilots can fall victim to using an unapproved part, creating a flight hazard that can lead to an accident. Aircraft manufacturers use hardware that meets multiple specifications that include shear strength, tensile strength, temperature range, working load, etc.

Tools for Hazard Awareness

There are some basic tools for helping recognize hazards.

Advisory Circulars (AC)

Advisory circulars (ACs) provide nonregulatory information for helping comply with 14 CFR. They amplify the intent of the regulation. For instance, AC 90-48, Pilot's Role in Collision Avoidance, provides information about the amount of time it takes to see, react, and avoid an oncoming aircraft.

For instance, if two aircraft are flying toward each other at 120 knots, that is a combined speed of 240 knots. The distance that the two aircraft are closing at each other is about 400 feet per second (403.2 fps). If the aircraft are one mile apart, it only takes 13 seconds (5,280 ÷ 400) for them to impact. According to AC 90-48, it takes a total of 12.5 seconds for the aircraft to react to a pilot's input after the pilot sees the other aircraft. [*Figure 1-1*]

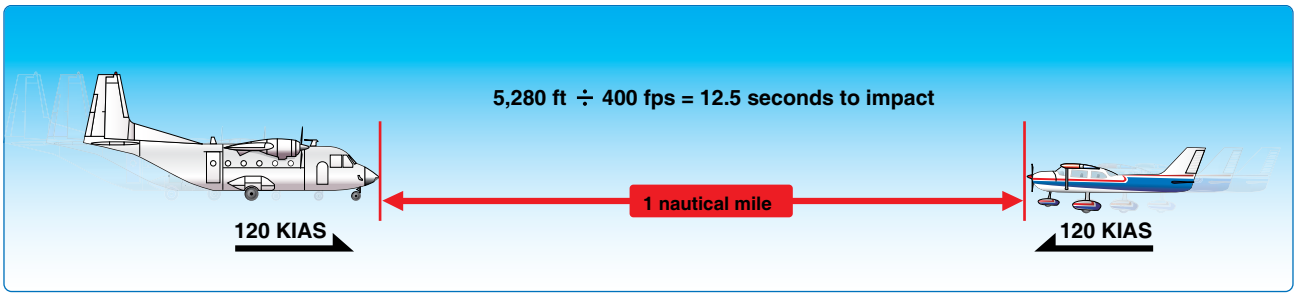


Figure 1-1. *Head-on approach impact time.*

Understanding the Dangers of Converging Aircraft

If a pilot sees an aircraft approaching at an angle and the aircraft's relationship to the pilot does not change, the aircraft will eventually impact. If an aircraft is spotted at 45° off the nose and that relationship remains constant, it will remain constant right up to the time of impact (45°). Therefore, if a pilot sees an aircraft on a converging course and the aircraft remains in the same position, change course, speed, altitude or all of these to avoid a midair collision.

Understanding Rate of Climb

In 2006, a 14 CFR part 135 operator for the United States military flying Casa 212s had an accident that would have been avoided with a basic understanding of rate of climb. The aircraft (flying in Afghanistan) was attempting to climb over the top ridge of a box canyon. The aircraft was climbing at 1,000 feet per minute (fpm) and about 1 mile from the canyon end. Unfortunately, the elevation change was also about 1,000 feet, making a safe ascent impossible. The aircraft hit the canyon wall about ½ way up the wall. How is this determined? The aircraft speed in knots multiplied by 1.68 equals the aircraft speed in feet per second (fps). For instance, in this case if the aircraft were traveling at about 150 knots, the speed per second is about 250 fps (150 x 1.68). If the aircraft is a nautical mile (NM) (6,076.1 feet) from the canyon end, divide the one NM by the aircraft speed. In this case, 6,000 feet divided by 250 is about 24 seconds. [*Figure 1-2*]

Understanding the Glide Distance

In another accident, the instructor of a Piper Apache feathered the left engine while the rated student pilot was executing an approach for landing in VFR conditions. Unfortunately, the student then feathered the right engine. Faced with a small tree line (containing scrub and small trees less than 10 feet in height) to his front, the instructor attempted to turn toward the runway. As most pilots know, executing a turn results in either decreased speed or increased descent rate, or requires more power to prevent the former. Starting from about 400 feet without power is not a viable position, and the sink rate on the aircraft is easily between 15 and 20 fps vertically. Once the instructor initiated the turn toward the runway, the sink rate was increased by the execution of the turn. [*Figure 1-3*] Adding to the complexity of the situation, the instructor attempted to unfeather the engines, which increased the drag, in turn increasing the rate of descent as the propellers started to turn. The aircraft stalled, leading to an uncontrolled impact. Had the instructor continued straight

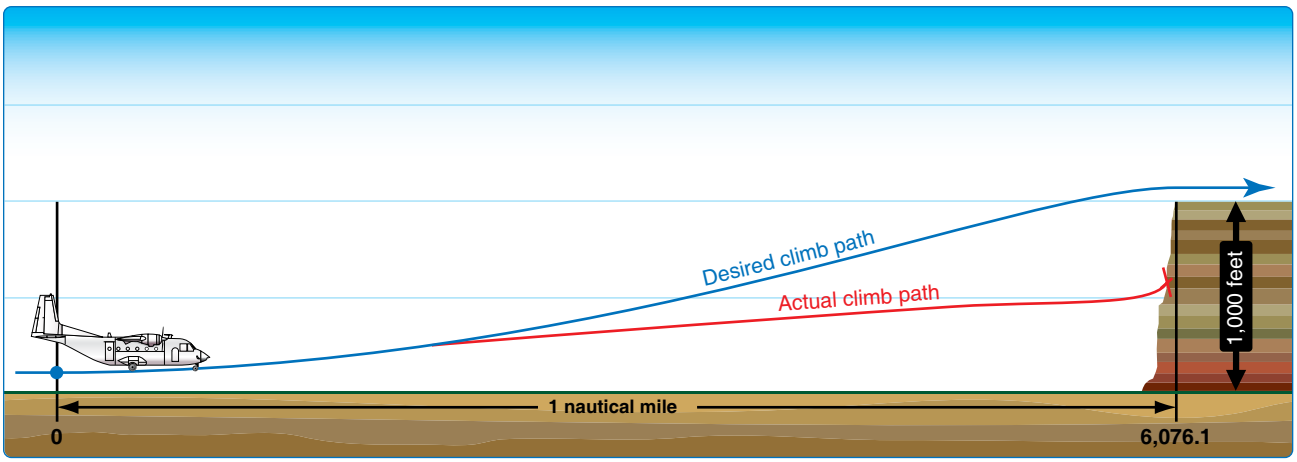


Figure 1-2. *The figure above is a scale drawing of an aircraft climbing at 1,000 fpm, located 1 NM from the end of the canyon and starting from the canyon floor 1,000 feet below the rim. The time to cover 6,000 feet is 24 seconds. With the aircraft climbing at 1,000 fps, in approximately ½ minute, the aircraft will climb only 500 feet and will not clear the rim.*

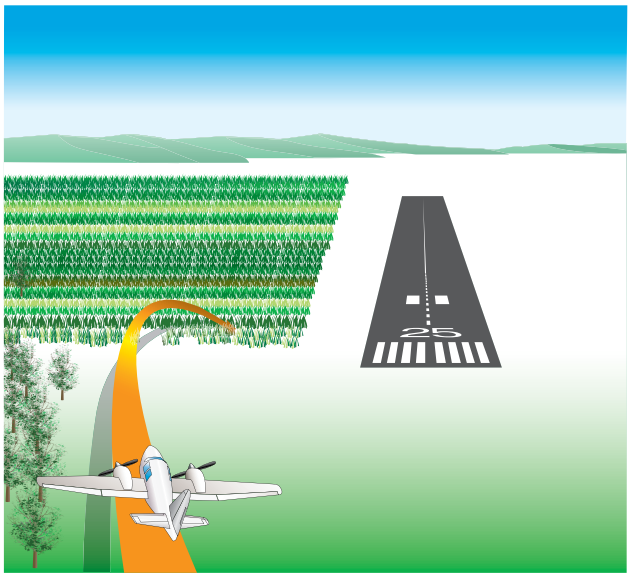


Figure 1-3. *In attempting to turn toward the runway, the instructor pilot landed short in an uncontrolled manner, destroying the aircraft and injuring both pilots.*

ahead, the aircraft would have at least been under control at the time of the impact.

There are several advantages to landing under control:

- The pilot can continue flying to miss the trees and land right side up to enhance escape from the aircraft after landing.
- If the aircraft lands right side up instead of nose down, or even upside down, there is more structure to absorb the impact stresses below the cockpit than there is above the cockpit in most aircraft.
- Less impact stress on the occupants means fewer injuries and a better chance of escape before fires begin.

Risk

Defining Risk

Risk is the future impact of a hazard that is not controlled or eliminated. It can be viewed as future uncertainty created by the hazard. If it involves skill sets, the same situation may yield different risk.

1. If the nick is not properly evaluated, the potential for propeller failure is unknown.
2. If the aircraft is not properly bonded and grounded, there is a build-up of static electricity that can and will seek the path of least resistance to ground. If the static discharge ignites the fuel vapor, an explosion may be imminent.
3. A fatigued pilot is not able to perform at a level commensurate with the mission requirements.
4. The owner of a homebuilt aircraft decides to use bolts from a local hardware store that cost less than the recommended hardware, but look the same and appear to be a perfect match, to attach and secure the aircraft wings. The potential for the wings to detach during flight is unknown.

In scenario 3, what level of risk does the fatigued pilot present? Is the risk equal in all scenarios and conditions? Probably not. For example, look at three different conditions in which the pilot could be flying:

1. Day visual meteorological conditions (VMC) flying visual flight rules (VFR)
2. Night VMC flying VFR
3. Night instrument meteorological conditions (IMC) flying instrument flight rules (IFR)

In these weather conditions, not only the mental acuity of the pilot but also the environment he or she operates within affects the risk level. For the relatively new pilot versus a highly experienced pilot, flying in weather, night experience, and familiarity with the area are assessed differently to determine potential risk. For example, the experienced pilot who typically flies at night may appear to be a low risk, but other factors such as fatigue could alter the risk assessment.

In scenario 4, what level of risk does the pilot who used the bolts from the local hardware center pose? The bolts look and feel the same as the recommended hardware, so why spend the extra money? What risk has this homebuilder created? The bolts purchased at the hardware center were simple low-strength material bolts while the wing bolts specified by the manufacturer were close-tolerance bolts that were corrosion resistant. The bolts the homebuilder employed to attach the wings would probably fail under the stress of takeoff.

Managing Risks

Risk is the degree of uncertainty. An examination of risk management yields many definitions, but it is a practical approach to managing uncertainty. [*Figure 1-4*] Risk assessment is a quantitative value assigned to a task, action, or event. [*Figure 1-5*] When armed with the predicted assessment of an activity, pilots are able to manage and reduce (mitigate) their risk. Take the use of improper hardware on a homebuilt aircraft for construction. Although one can easily see both the hazard is high and the severity is extreme, it does take the person who is using those bolts to recognize the risk. Otherwise, as is in many cases, the chart in *Figure 1-5* is used after the fact. Managing risk takes discipline in separating oneself from the activity at hand in order to view the situation as an unbiased evaluator versus

Types of Risk	
Total Risk	The sum of identified and unidentified risks.
Identified Risk	Risk that has been determined through various analysis techniques. The first task of system safety is to identify, within practical limitations, all possible risks.
Unidentified Risk	Risk not yet identified. Some unidentified risks are subsequently identified when a mishap occurs. Some risk is never known.
Unacceptable Risk	Risk that cannot be tolerated by the managing activity. It is a subset of identified risk that must be eliminated or controlled.
Acceptable Risk	Acceptable risk is the part of identified risk that is allowed to persist without further engineering or management action. Making this decision is a difficult yet necessary responsibility of the managing activity. This decision is made with full knowledge that it is the user who is exposed to this risk.
Residual Risk	Residual risk is the risk remaining after system safety efforts have been fully employed. It is not necessarily the same as acceptable risk. Residual risk is the sum of acceptable risk and unidentified risk. This is the total risk passed on to the user.

Figure 1-4. *Types of risk.*

Risk Assessment Matrix				
Likelihood	Severity			
	Catastrophic	Critical	Marginal	Negligible
Probable	High	High	Serious	
Occasional	High	Serious		
Remote	Serious	Medium		Low
Improbable				

Figure 1-5. *Using a risk assessment matrix helps the pilot differentiate between low-risk and high-risk flights.*

an eager participant with a stake in the flight's execution. Another simple step is to ask three questions—is it safe, is it legal, and does it make sense? Although not a formal methodology of risk assessment, it prompts a pilot to look at the simple realities of what he or she is about to do.

Therefore, risk management is the method used to control, eliminate, or reduce the hazard within parameters of acceptability. Risk management is unique to each and every individual, since there are no two people exactly alike in skills, knowledge, training, and abilities. An acceptable level of risk to one pilot may not necessarily be the same to another pilot. Unfortunately, in many cases the pilot perceives that his or her level of risk acceptability is actually greater than their capability thereby taking on risk that is dangerous.

It is a decision-making process designed to systematically identify hazards, assess the degree of risk, and determine the best course of action. Once risks are identified, they must be assessed. The risk assessment determines the degree of risk (negligible, low, medium, or high) and whether the degree of risk is worth the outcome of the planned activity. If the degree of risk is "acceptable," the planned activity may then be undertaken. Once the planned activity is started, consideration must then be given whether to continue. Pilots must have viable alternatives available in the event the original flight cannot be accomplished as planned.

Thus, hazard and risk are the two defining elements of risk management. A hazard can be a real or perceived condition, event, or circumstance that a pilot encounters.

Consider the example of a flight involving a Beechcraft King Air. The pilot was attempting to land in a northern Michigan airport. The forecasted ceilings were at 500 feet with ½ mile visibility. He deliberately flew below the approach minimums, ducked under the clouds, and struck the ground killing all on board. A prudent pilot would assess the risk in this case as high and beyond not only the capabilities of the aircraft and the pilot but beyond the regulatory limitations established for flight. The pilot failed to take into account the hazards associated with operating an aircraft in low ceiling and low visibility conditions.

A review of the accident provides a closer look at why the accident happened. If the King Air were traveling at 140 knots or 14,177 feet per minute, it would cover ½ statute mile (sm) visibility (2,640 feet) in about 11 seconds. As determined in *Figure 1-1,* the pilot has 12.5 seconds to impact. This example states that the King Air is traveling ½ statute mile every 11 seconds, so if the pilot only had ½ sm visibility, the aircraft will impact before the pilot can react. These factors make flight in low ceiling and low visibility conditions extremely hazardous. Chapter 4, Aerodynamics of Flight, of the Pilot's Handbook of Aeronautical Knowledge presents a discussion of space required to maneuver an aircraft at various airspeed.

So, why would a pilot faced with such hazards place those hazards at such a low level of risk? To understand this, it is important to examine the pilot's past performance. The pilot had successfully flown into this airport under similar

conditions as these despite the apparent risk. This time, however, the conditions were forecast with surface fog. Additionally, the pilot and his passenger were in a hurry. They were both late for their respective appointments. Perhaps being in a hurry, the pilot failed to factor in the difference between the forecasted weather and weather he negotiated before. Can it be said that the pilot was in a hurry definitively? Two years before this accident, the pilot landed a different aircraft gear up. At that incident, he simply told the fixed-base operator (FBO) at the airport to take care of the aircraft because the pilot needed to go to a meeting. He also had an enforcement action for flying low over a populated area.

It is apparent that this pilot knew the difference between right and wrong. He elected to ignore the magnitude of the hazard, the final illustration of a behavioral problem that ultimately caused this accident. Certainly one would say that he was impetuous and had what is called "get there itis." While ducking under clouds to get into the Michigan airport, the pilot struck terrain killing everyone onboard. His erroneous behavior resulted from inadequate or incorrect perceptions of the risk, and his skills, knowledge, and judgment were not sufficient to manage the risk or safely complete the tasks in that aircraft. [*Figure 1-6*]

Figure 1-6. *Each pilot may have a different threshold where skill is considered, however; in this case no amount of skill raises this line to a higher level.*

The hazards a pilot faces and those that are created through adverse attitude predispose his or her actions. Predisposition is formed from the pilot's foundation of beliefs and, therefore, affects all decisions he or she makes. These are called "hazardous attitudes" and are explained in the Pilot's Handbook of Aeronautical Knowledge, Chapter 17, Aeronautical Decision-Making.

A key point must be understood about risk. Once the situation builds in complexity, it exceeds the pilot's capability and requires luck to succeed and prevail. [*Figure 1-7*]

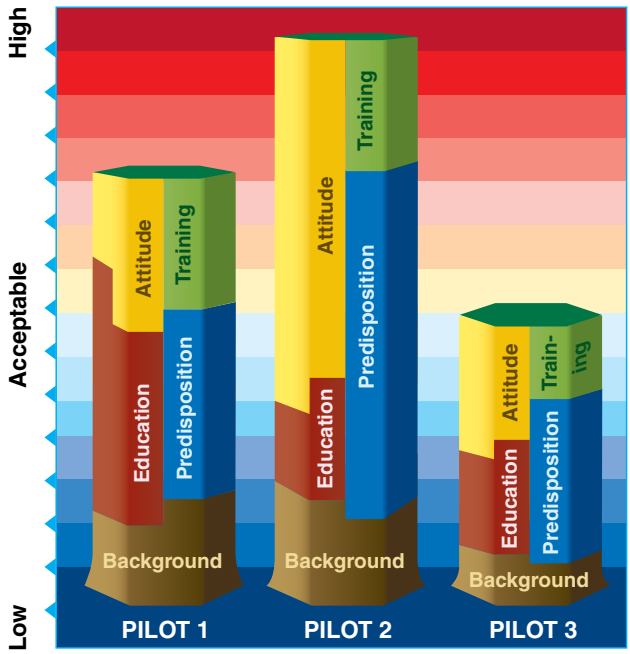


Figure 1-7. *Pilots accept their own individual level of risk even though they may have received similar training. Risk, which must be managed individually, becomes a problem when a situation builds and its complexity exceeds the pilot's capability (background + education + predisposition + attitude + training). The key to managing risk is the pilot's understanding of his or her threshold and perceptions of the risk.*

Unfortunately, when a pilot survives a situation above his or her normal capability, perception of the risk involved and of the ability to cope with that level of risk become skewed. The pilot is encouraged to use the same response to the same perceived level of risk, viewing any success as due to skill, not luck. The failure to accurately perceive the risk involved and the level of skill, knowledge, and abilities required to mitigate that risk may influence the pilot to accept that level of risk or higher levels.

Many in the aviation community would ask why the pilot did not see this action as a dangerous maneuver. The aviation community needs to ask questions and develop answers to these questions: "What do we need to do during the training and education of pilots to enable them to perceive these hazards as risks and mitigate the risk factors?" "Why was this

pilot not trained to ask for an approach clearance and safely fly an approach or turned around and divert to an airport with better weather?" Most observers view this approach as not only dangerous but also lacking common sense. To further understand this action, a closer look at human behavior is provided in Chapter 2, Studies of Human Behavior.

Chapter Summary

The concepts of hazard and risk are the core elements of risk management. Types of risk and the experience of the pilot determine that individual's acceptable level of risk.