

4. Failure to consider emergency landing areas.
5. Failure to select a specific landing spot.
6. Failure to consider how wind and turbulence could affect the approach.
7. Improper takeoff and climb technique for existing conditions.
8. Failure to maintain safe clearance distance from obstructions.

Pinnacle and Ridgeline Operations

A pinnacle is an area from which the surface drops away steeply on all sides. A ridgeline is a long area from which the surface drops away steeply on one or two sides, such as a bluff or precipice. The absence of obstacles does not necessarily decrease the difficulty of pinnacle or ridgeline operations. Updrafts, downdrafts, and turbulence, together with unsuitable terrain in which to make a forced landing, may still present extreme hazards.

Approach and Landing

If there is a need to climb to a pinnacle or ridgeline, do it on the upwind side, when practicable, to take advantage of any updrafts. The approach flightpath should be parallel to the ridgeline and into the wind as much as possible. [Figure 10-9]

Load, altitude, wind conditions, and terrain features determine the angle to use in the final part of an approach. As a general rule, the greater the winds are, the steeper the approach needs to be to avoid turbulent air and downdrafts.

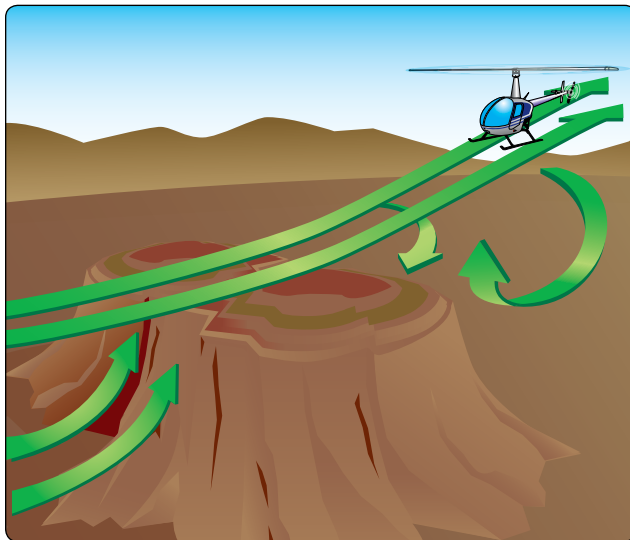


Figure 10-9. When flying an approach to a pinnacle or ridgeline, avoid the areas where downdrafts are present, especially when excess power is limited. If downdrafts are encountered, it may become necessary to make an immediate turn away from the pinnacle to avoid being forced into the rising terrain.

Groundspeed during a pinnacle approach is more difficult to judge because visual references are farther away than during approaches over trees or flat terrain. Pilots must continually perceive the apparent rate of closure by observing the apparent change in size of the landing zone features. Avoid the misperception of an increasing rate of closure to the landing site. The apparent rate of closure should be that of a brisk walk. If a crosswind exists, remain clear of down-drafts on the leeward or downwind side of the ridgeline. If the wind velocity makes the crosswind landing hazardous, it may be possible to make a low, coordinated turn into the wind just prior to terminating the approach. When making an approach to a pinnacle, avoid leeward turbulence and keep the helicopter within reach of a forced landing area as long as possible.

On landing, take advantage of the long axis of the area when wind conditions permit. Touchdown should be made in the forward portion of the area. When approaching to land on pinnacles, especially manmade areas such as rooftop pads, the pilot should determine the personnel access pathway to the helipad and ensure that the tail rotor is not allowed to intrude into that walkway or zone. Parking or landing with the tail rotor off the platform ensures personnel safety. Always perform a stability check prior to reducing rpm to ensure the landing gear is on firm terrain that can safely support the weight of the helicopter. Accomplish this by slowly moving the cyclic and pedals while lowering the collective. If movement is detected, reposition the aircraft.

Takeoff

A pinnacle takeoff is considered an airspeed over altitude maneuver which can be made from the ground or from a hover. Since pinnacles and ridgelines are generally higher than the immediate surrounding terrain, gaining airspeed on the takeoff is more important than gaining altitude. As airspeed increases, the departure from the pinnacle becomes more rapid, and helicopter time in the *avoid* area of the height/velocity area decreases. [Figure 11-3] In addition to covering unfavorable terrain rapidly, a higher airspeed affords a more favorable glide angle and thus contributes to the chances of reaching a safe area in the event of a forced landing. If a suitable forced landing area is not available, a higher airspeed also permits a more effective flare prior to making an autorotative landing.

On takeoff, as the helicopter moves out of ground effect, maintain altitude and accelerate to normal climb airspeed. When normal climb speed is attained, establish a normal climb attitude. Never dive the helicopter down the slope after clearing the pinnacle.

Common Errors

1. Failing to perform, or improper performance of, a high or low reconnaissance.
2. Flying the approach angle too steep or too shallow for the existing conditions.
3. Failing to maintain proper rpm.
4. Failing to consider emergency landing areas.
5. Failing to consider how wind and turbulence could affect the approach and takeoff.
6. Failure to maintain pinnacle elevation after takeoff.
7. Failure to maintain proper approach rate of closure.
8. Failure to achieve climb airspeed in timely manner.

Chapter Summary

This chapter described advanced flight maneuvers such as slope landings, confined area landings, and running takeoffs. The correlation between helicopter performance requirements, the environmental factors associated with different flight techniques, and safety considerations were also explained to familiarize the pilot with the measures that can be taken when performing these maneuvers to mitigate risks. Hazards associated with helicopter flight and certain aerodynamic considerations were also discussed.

Chapter 11

Helicopter Emergencies and Hazards

Introduction

Today, helicopters are quite reliable. However, emergencies do occur, whether a result of mechanical failure or pilot error, and should be anticipated. Regardless of the cause, the recovery needs to be quick and precise. By having a thorough knowledge of the helicopter and its systems, a pilot is able to handle the situation more readily. Helicopter emergencies and the proper recovery procedures should be discussed and, when possible, practiced in flight. In addition, by knowing the conditions that can lead to an emergency, many potential accidents can be avoided.



Autorotation

In a helicopter, an autorotative descent is a power-off maneuver in which the engine is disengaged from the main rotor disk and the rotor blades are driven solely by the upward flow of air through the rotor. [Figure 11-1] In other words, the engine is no longer supplying power to the main rotor.

The most common reason for an autorotation is failure of the engine or drive line, but autorotation may also be performed in the event of a complete tail rotor failure, since there is virtually no torque produced in an autorotation. In both cases, maintenance has often been a contributing factor to the failure. Engine failures are also caused by fuel contamination or exhaustion as well resulting in a forced autorotation.

If the engine fails, the freewheeling unit automatically disengages the engine from the main rotor, allowing it to rotate freely. Essentially, the freewheeling unit disengages anytime the engine revolutions per minute (rpm) is less than the rotor rpm.

At the instant of engine failure, the main rotor blades are producing lift and thrust from their angle of attack (AOA) and velocity. By lowering the collective (which must be done immediately in case of an engine failure), lift and drag are reduced, and the helicopter begins an immediate descent, thus producing an upward flow of air through the rotor disk. This upward flow of air through the rotor disk provides sufficient thrust to maintain rotor rpm throughout the descent. Since the tail rotor is driven by the main rotor transmission during autorotation, heading control is maintained with the antitorque pedals as in normal flight.

Several factors affect the rate of descent in autorotation: bank angle, density altitude, gross weight, rotor rpm, trim condition, and airspeed. The primary ways to control the rate of descent are with airspeed and rotor rpm. Higher or lower airspeed is obtained with the cyclic pitch control just as in normal powered flight. In theory, a pilot has a choice in the angle of descent, varying, from straight vertical to maximum horizontal range (which is the minimum angle of descent). Rate of descent is high at zero airspeed and decreases to a minimum at approximately 50–60 knots, depending upon the particular helicopter and the factors just mentioned. As the airspeed increases beyond that which gives minimum rate of descent, the rate of descent increases again.

When landing from an autorotation, the only energy available to arrest the descent rate and ensure a soft landing is the kinetic energy stored in the rotor blades. Tip weights can greatly increase this stored energy. A greater amount of rotor energy is required to stop a helicopter with a high rate of descent than is required to stop a helicopter that is descending more slowly. Therefore, autorotative descents at very low or very high airspeeds are more critical than those performed at the minimum rate of descent airspeed. Refer to the height/velocity diagram discussion in Chapter 7, Helicopter Performance.

Each type of helicopter has a specific airspeed and rotor rpm at which a power-off glide is most efficient. The specific airspeed is somewhat different for each type of helicopter, but certain factors affect all configurations in the same manner. In general, rotor rpm maintained in the low green area (see Figure 5-3) gives more distance in an autorotation. Heavier helicopter weights may require more collective to control rotor rpm. Some helicopters need slight adjustments to minimum rotor rpm settings for winter versus summer

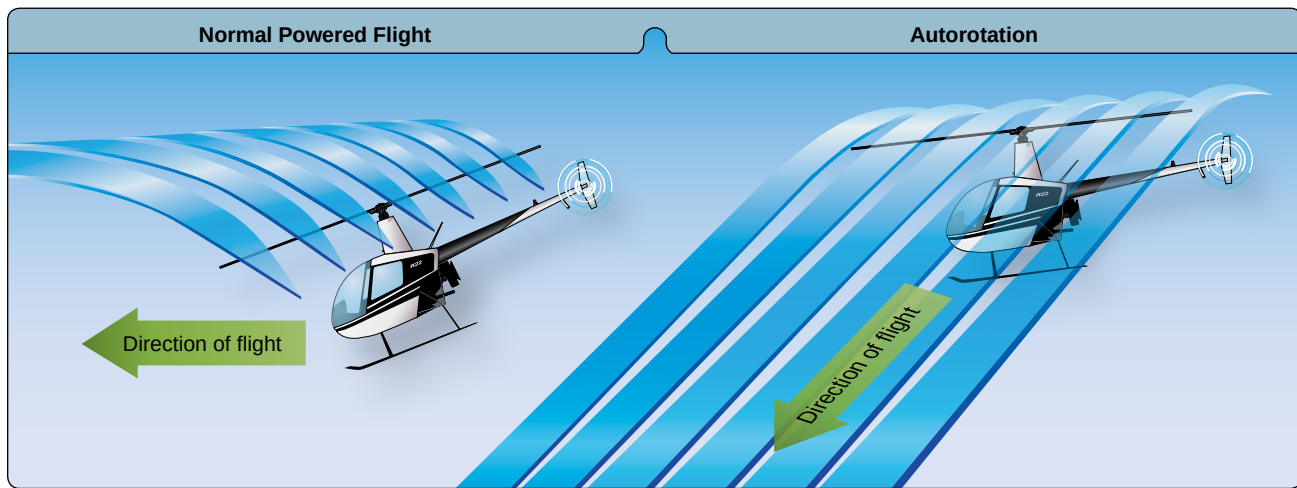


Figure 11-1. During an autorotation, the upward flow of relative wind permits the main rotor blades to rotate at their normal speed. In effect, the blades are “gliding” in their rotational plane.

conditions, and high altitude versus sea level flights. For specific autorotation airspeed and rotor rpm combinations for a particular helicopter, refer to the Rotorcraft Flight Manual (RFM). The specific airspeed and rotor rpm for autorotation is established for each type of helicopter based on average weather, calm wind conditions, and normal loading. When the helicopter is operated with heavy loads in high density altitude or gusty wind conditions, best performance is achieved from a slightly increased airspeed in the descent. For autorotation at low density altitude and light loading, best performance is achieved from a slight decrease in normal airspeed. Following this general procedure of fitting airspeed and rotor rpm to existing conditions, a pilot can achieve approximately the same glide angle in any set of circumstances, and thereby estimate the touchdown point accurately.

It is important that pilots experience autorotations from various airspeeds. This provides better understanding of the necessary flight control inputs to achieve the desired airspeed, rotor rpm and autorotation performance, such as the maximum glide or minimum descent airspeed. The decision to use the appropriate airspeed and rotor rpm for the given conditions should be instinctive to reach a suitable landing area. The helicopter glide ratio is much less than that of a fixed-wing aircraft and takes some getting used to. The flare to land at 80 knots indicated airspeed (KIAS) will be significantly greater than that from 55 KIAS. Rotor rpm control is critical at these points to ensure adequate rotor energy for cushioning the landing.

Use collective pitch control to manage rotor rpm. If rotor rpm builds too high during an autorotation, raise the collective sufficiently to decrease rpm back to the normal operating range, then reduce the collective to maintain proper rotor rpm. If the collective increase is held too long, the rotor rpm may decay rapidly. The pilot would have to lower the collective in order to regain rotor rpm. If the rpm begins decreasing, the pilot must again lower the collective. Always keep the rotor rpm within the established recommended range for the helicopter being flown.

RPM Control

Rotor rpm in low inertia rotor systems has been studied in simulator flight evaluations which indicate that the simultaneous application of aft cyclic, down collective, and alignment with the relative wind (trim) at a wide range of airspeeds, including cruise airspeeds, is critical for all operations during the entry of an autorotation. The applicable Rotorcraft Flight Manual (RFM) should be consulted to determine the appropriate procedure(s) for safely entering an autorotation. This is vitally important since the procedure(s) for safely entering an autorotation may vary with specific makes and/or models of helicopters. A basic discussion of

the aerodynamics and control inputs for single rotor systems is in order here.

Helicopter pilots must understand the use of the collective for rotor rpm control during power off autorotations in a turn. Upward movement of the collective reduces the rpm and downward movement increases the rpm. Cyclic movement is primarily associated with attitude/airspeed control in powered flight but may not be given the credit appropriate for rotor rpm control during practice and emergency power off autorotations. As long as the line of cyclic movement is parallel with the flight path of the helicopter (trimmed), the aft movement of the cyclic also creates greater air flow up through the bottom of the rotor disk and contributes to an increase in rotor rpm. If the flight path is 10 degrees to the right of the longitudinal axis of the helicopter, theoretically, the cyclic should be moved 10 degrees aft and left of the longitudinal axis to get maximum air up through the rotor system.

As the pilot lowers the collective in reaction to a loss of power during cruise flight there may be a tendency for the nose of the helicopter to pitch down. As a result, the pilot may tend to lean forward slightly, which delays the application of simultaneous aft cyclic to prevent the pitch change and associated loss of rotor rpm. A slight gain in altitude at cruise airspeed during the power off entry into an autorotation should not be of great concern as is the case for the execution of practice or actual quick stops.

Various accident investigations have concluded that, when faced with a real power failure at cruise airspeed, pilots are not simultaneously applying down collective, aft cyclic, and antitorque pedal inputs in a timely manner. Low inertia rotor systems store less kinetic energy during autorotation and, as a result, rotor rpm decays rapidly during deceleration and touchdown. Conversely, less energy is required to regain safe rotor rpm during autorotation entry and autorotative descent. The pilot should immediately apply simultaneous down collective, aft cyclic and trim the helicopter for entry into an autorotation initiated at cruise airspeed. If rotor rpm has been allowed to decrease, or has inadvertently decreased below acceptable limits, an application of aft cyclic may help rebuild rotor rpm. This application of aft cyclic must be made at least at a moderate rate and may be combined with a turn, either left or right, to increase airflow through the rotor system. This will work to increase rotor rpm. Care should be maintained to not over-speed the rotor system as this is attempted.

Risk Management during Autorotation Training

The following sections describe enhanced guidelines for autorotations during rotorcraft/helicopter flight training, as stated in Advisory Circular (AC) 61-140. There are

risks inherent in performing autorotations in the training environment, and in particular the 180-degree autorotation. This section describes an acceptable means, but not the only means, of training applicants for a rotorcraft/helicopter airman certificate to meet the qualifications for various rotorcraft/helicopter ratings. You may use alternate methods for training if you establish that those methods meet the requirements of the Helicopter Flying Handbook (HFH), FAA practical test standards (PTS), and the Rotorcraft Flight Manual (RFM).

Straight-In Autorotation

A straight-in autorotation is one made from altitude with no turns. Winds have a great effect on an autorotation. Strong headwinds cause the glide angle to be steeper due to the slower groundspeed. For example, if the helicopter is maintaining 60 KIAS and the wind speed is 15 knots, then the groundspeed is 45 knots. The angle of descent will be much steeper, although the rate of descent remains the same. The speed at touchdown and the resulting ground run depend on the groundspeed and amount of deceleration. The greater the degree of deceleration, or flare, and the longer it is held, the slower the touchdown speed and the shorter the ground run. Caution must be exercised at this point as the tail rotor will be the component of the helicopter closest to the ground. If timing is not correct and a landing attitude not set at the appropriate time, the tail rotor may contact the ground causing a forward pitching moment of the nose and possible damage to the helicopter.

A headwind is a contributing factor in accomplishing a slow touchdown from an autorotative descent and reduces the amount of deceleration required. The lower the speed desired at touchdown, the more accurate the timing and speed of the flare must be, especially in helicopters with low-inertia rotor disks. If too much collective is applied too early during the final stages of the autorotation, the kinetic energy may be depleted, resulting in little or no cushioning effect available. This could result in a hard landing with corresponding damage to the helicopter. It is generally better practice to accept more ground run than a harder landing with minimal groundspeed. As proficiency increases, the amount of ground run may be reduced.

Technique (How to Practice)

Refer to *Figure 11-2* (position 1). From level flight at the appropriate airspeed (cruise or the manufacturer's recommended airspeed), 500–700 feet above ground level (AGL), and heading into the wind, smoothly but firmly lower the collective to the full down position. Use aft cyclic to prevent a nose low attitude while maintaining rotor rpm in the green arc with collective. If the collective is in the full down position, the rotor rpm is then being controlled by

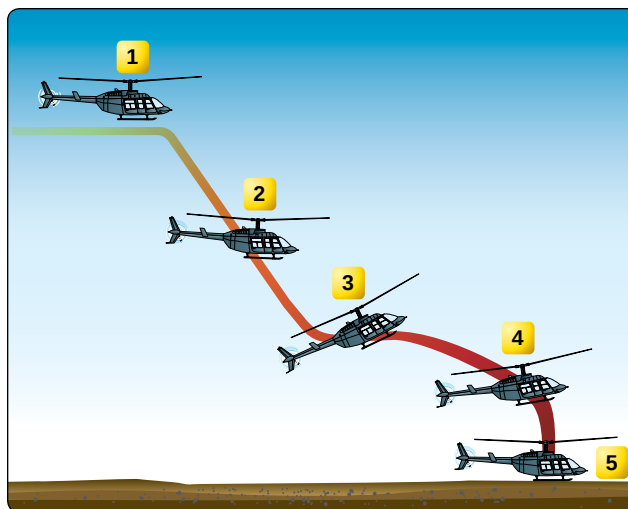


Figure 11-2. *Straight-in autorotation.*

the mechanical pitch stops. During maintenance, the rotor stops must be set to allow minimum autorotational rpm with a light loading. This means that collective will still be able to be reduced even under conditions of extreme reduction of vertical loading (e.g., very low helicopter weight, at very low-density altitude). After entering an autorotation, collective pitch must be adjusted to maintain the desired rotor rpm.

Coordinate the collective movement with proper antitorque pedal for trim, and apply cyclic control to maintain proper airspeed. Once the collective is fully lowered, decrease throttle to ensure a clean split/separation of the needles. This means that the rotor rpm increases to a rate higher than that of the engine—a clear indication that the freewheeling unit has allowed the engine to disconnect. After splitting the needles, readjust the throttle to keep engine rpm above normal idling speed, but not high enough to cause rejoining of the needles. See the RFM for the manufacturer's recommendations for autorotation rate of descent.

At position 2, adjust attitude with cyclic to obtain the manufacturer's recommended autorotation (or best gliding) speed. Adjust collective as necessary to maintain rotor rpm in the lower part of the green arc (see page 11-2). Aft cyclic movements cause an increase in rotor rpm, which is then controlled by a small increase in collective. Avoid a large collective increase, which results in a rapid decay of rotor rpm, and leads to "chasing the rpm." Avoid looking straight down in front of the aircraft. Continually crosscheck attitude, trim, rotor rpm, and airspeed.

At the altitude recommended by the manufacturer (position 3), begin the flare with aft cyclic to reduce forward airspeed and decrease the rate of descent. Maintain heading with the antitorque pedals. During the flare, maintain rotor rpm in

the green range. In the execution of the flare, care must be taken that the cyclic be moved rearward neither so abruptly that it causes the helicopter to climb, nor so slowly that it fails to arrest the descent, which may allow the helicopter to settle so rapidly that the tail rotor strikes the ground. In most helicopters, the proper flare attitude is that resulting in a groundspeed of a slow run. When forward motion decreases to the desired groundspeed—usually the lowest possible speed (position 4)—move the cyclic forward to place the helicopter in the proper attitude for landing.

This action gives the student an idea of airframe attitude to avoid, because a pilot should never allow ground contact unless the helicopter is more nose-low than that attitude. Limiting the flare to that attitude may result in slightly faster touchdown speeds but will eliminate the possibility of tail rotor impact on level surfaces.

The landing gear height at this time should be approximately 3–15 feet AGL, depending on the altitude recommended by the manufacturer. As the apparent groundspeed and altitude decrease, the helicopter must be returned to a more level attitude for touchdown by applying forward cyclic. Some helicopters can be landed on the heels in a slightly nose high attitude to help decrease the forward groundspeed, whereas others must land skids or landing gear level, in order to spread the landing loads equally to all of the landing gear. Extreme caution should be used to avoid an excessive nose high and tail low attitude below 10 feet. The helicopter must be close to the landing attitude to keep the tail rotor from contacting the surface.

At this point, if a full touchdown landing is to be performed, allow the helicopter to descend vertically (position 5). This collective application uses some of the kinetic energy in the rotor disk to help slow the descent rate of the helicopter. When the collective is raised, the opposite antitorque pedal used in powered flight will be needed due to the friction within the transmission/drive train. Touch down in a level flight attitude.

Control response with increased pitch angles will be slightly different than normal. With a decrease in main rotor rpm, the antitorque authority is reduced (the pedals react more slowly), requiring larger control inputs to maintain heading at touchdown.

Some helicopters, such as the Schweizer 300, have a canted tail stabilizer. With a canted stabilizer, it is crucial that the pilot apply the appropriate pedal input at all times during the autorotation. If not the tailboom tends to swing to the right, which allows the canted stabilizer to raise the tail. This can

result in a severe nose tuck which is quickly corrected with right pedal application.

A power recovery can be made during training in lieu of a full touchdown landing. Refer to the section on power recovery for the correct technique.

After the helicopter has come to a complete stop after touchdown, lower the collective pitch to the full-down position. Do not try to stop the forward ground run with aft cyclic, as the main rotor blades can strike the tail boom. By lowering the collective slightly during the ground run, an increase in weight is placed on the landing carriage, slowing the helicopter; however, this is dependent on the condition of the landing surface.

One common error is the holding of the helicopter off the surface, versus cushioning it onto the surface during an autorotation. Holding the helicopter in the air by using all of the rotor rpm kinetic energy usually causes the helicopter to have a hard landing, which results in the blades flexing down and contacting the tail boom. The rotor rpm should be used to cushion the helicopter on to the surface for a controlled, smooth landing instead of allowing the helicopter to drop the last few inches.

Common Errors

1. Not understanding the importance of an immediate entry into autorotation upon powerplant or driveline failure.
2. Failing to use sufficient antitorque pedal when power is reduced.
3. Lowering the nose too abruptly when power is reduced, thus placing the helicopter in a dive.
4. Failing to maintain proper rotor rpm during the descent.
5. Applying up-collective pitch at an excessive altitude, resulting in a hard landing, loss of heading control, and possible damage to the tail rotor and main rotor blade stops.
6. Failing to level the helicopter or achieve the manufacturers preferred landing attitude.
7. Failing to minimize or eliminate lateral movement during ground contact. (Similar for items 8 and 9)
8. Failing to maintain ground track in the air and keeping the landing gear aligned with the direction of travel during touchdown and ground contact.
9. Failing (in a practice run) to go around if not within limits and specified criteria for safe autorotation.

Autorotation with Turns

Turns (or a series of turns) can be made during autorotation to facilitate landing into the wind or avoiding obstacles. Turns during autorotation should be made early so that the remainder of the autorotation is flown identically to a straight-in autorotation. The most common turns in an autorotation are 90 degrees and 180 degrees. The following technique describes an autorotation with a 180-degree turn.

The pilot establishes the aircraft on a downwind heading at the recommended airspeed, and parallel to the intended touchdown point. Then, taking the wind into account, the pilot establishes the ground track approximately 200 feet laterally from the desired course line to the touchdown point. In strong crosswind conditions, the pilot should be prepared to adjust the downwind leg closer or farther out, as appropriate. The pilot uses the autorotation entry airspeed recommended by the RFM. When abeam the intended touchdown point, the pilot smoothly reduces collective, then reduces power to the engine to show a split between the rotor rpm and engine rpm and simultaneously applies appropriate anti-torque pedal and cyclic to maintain proper attitude/airspeed. Throughout the autorotation, the pilot should continually crosscheck the helicopter's attitude, rotor rpm, airspeed, and verify that the helicopter is in trim (centered trim ball).

After the descent and autorotation airspeed is established, the pilot initiates the 180-degree turn. For training operations, initially roll into a bank of at least 30 degrees, but no more than 60 degrees. It is important to maintain the proper airspeed, rotor rpm, and trim (centered trim ball) throughout the turn. Changes in the helicopter's attitude and the angle of bank causes a corresponding change in rotor rpm within normal limits. Do not allow the nose to pitch up or down excessively during the maneuver, as it may cause undesirable rotor rpm excursions.

Pitot-static airspeed indications may be unreliable or lag during an autorotational turn. The pilot should exercise caution to avoid using excessive aircraft pitch attitudes and to avoid chasing airspeed indications in an autorotational turn.

Note: Approaching the 90-degree point, check the position of the landing area. The second 90 degrees of the turn should end with a roll-out on a course line to the landing area. If the helicopter is too close, decrease the bank angle (to increase the radius of turn); if too far out, increase the bank angle (to decrease the radius of the turn). A bank angle of no more than 60 degrees should be encountered during this turn. Monitor the trim ball (along with one's kinesthetic sense) and adjust as necessary with cyclic and anti-torque pedal to maintain coordinated flight. Prior to passing through 200 feet above ground level (AGL), if landing or making a

surface-level power recovery, the turn should be completed, and the helicopter aligned with the intended touchdown area. Upon reaching the course line, set the appropriate crosswind correction. If the collective pitch was increased to control the rpm, it may need to be lowered on rollout to prevent decay in rotor rpm.

This maneuver should be aborted at any point the following criteria is not met: if the helicopter is not in a stabilized approach to landing profile (i.e., it is not aligned as close as possible into the wind with the touchdown point, after completing the 180-degree turn); if the rotor rpm is not within limits; if the helicopter is not at a proper attitude/airspeed; or if the helicopter is not under proper control at 200 feet AGL. It is essential that the pilot on the controls (or a certificated flight instructor (CFI), when intervening) immediately abort the maneuver and execute a smooth power recovery and go-around. It is important for the CFI who is intervening at this point to remember that the go-around is a far safer option than trying to recover lost rotor rpm and reestablish or recover to the hover or even the preferred hover taxi.

From all entry positions, but particularly true of the 180-degree entry, a primary concern is getting the aircraft into the course line with as much altitude as possible. Once the collective has been lowered and the engine set to flight idle, the helicopter will lose altitude. A delayed turn will result in a lower altitude when arriving on the course line. Additionally, an uncoordinated flight condition (trim-ball not centered) results in an increased sink rate, which may be unrecoverable if not corrected.

During the turn to the course line, the pilot should use a scan pattern to see outside as well as inside the cockpit. Of primary importance outside is maintaining the appropriate descending attitude and a proper turn rate. Essential items to scan inside are rotor rpm and centered trim ball. Rotor rpm will build anytime "G" forces are applied to the rotor system. Usually, this occurs in the turn to the course line and during the deceleration flare.

Throughout the maneuver, rotor rpm should be maintained in the range recommended in the RFM. Rotor rpm outside of the recommended range results in a higher rate of descent and less glide-ratio. When the rotor rpm exceeds the desired value as a result of increased G load in the turn, timely use of up collective will increase the pitch of the blades and slow the rotor to the desired rpm. In an autorotation, rotor rpm is the most critical element, as it provides the lift required to stabilize an acceptable rate of descent and the energy necessary to cushion the landing. Collective should be lowered to the full down position to maintain rotor rpm immediately following a loss of power. However, rapid or

abrupt collective movement could lead to mast bumping in some rotorcraft with teetering rotor systems.

Energy is a very important property of all rotating components, and the kinetic energy stored in the rotor system is used to cushion the landing. More lift is produced at the bottom of an autorotation by raising the collective, which increases the angle of attack of the blades. The rotor rpm will also rapidly decay at this point and it is essential to properly time the flare and the final collective pull to fully arrest the descent and cushion the landing. Upon arriving into the course line prior to the flare, the scan should focus almost entirely outside. The scan should include:

- The horizon for attitude, ground track, and nose alignment;
- the altitude to set the flare and for closure (groundspeed); and
- the instrument cross-check of airspeed, rotor rpm, and engine rpm in the descent.

Every autorotational flare will be different depending on the existing wind conditions, airspeed, density altitude (DA), and the aircraft gross weight. A pilot operating a helicopter at a high DA needs to take into account the effects on the control of the helicopter when recovering from an aborted autorotation.

Some effects to consider are:

- Higher rate of descent.
- Reduced rotor rpm builds in autorotation.
- Low initial rotor rpm response in autorotation.
- The requirement for a higher flare height.
- Reduced engine power performance.

Common Errors

The following common errors should be prevented:

1. Entering the maneuver at an improper altitude or airspeed.
2. Entering the maneuver without a level attitude (or not in coordinated flight).
3. Entering the maneuver and not correcting from the initial deceleration to a steady state attitude (which allows excessive airspeed loss in the descent).
4. Improper transition into the descent on entry.
5. Improper use of anti-torque on entry.
6. Failure to establish the appropriate crosswind correction, allowing the aircraft to drift.
7. Failure to maintain coordinated flight through the turn.

8. Failure to maintain rotor rpm within the RFM recommended range.
9. Excessive yaw when increasing collective to slow rate of descent during power recovery autorotations.
10. During power recovery autorotations, a delay in reapplying power.
11. Initial collective pull either too high or too low.
12. Improper flare (too much or not enough).
13. Flaring too low or too high (AGL).
14. Failure to maintain heading when reapplying power.
15. Not landing with a level attitude.
16. Landing with aircraft not aligned with the direction of travel.
17. Insufficient collective cushioning during full autorotations.
18. Abrupt control inputs on touchdown during full autorotations.

Practice Autorotation with a Power Recovery

A power recovery is used to terminate practice autorotations at a point prior to actual touchdown. After the power recovery, a landing can be made or a go-around initiated.

Technique (How to Practice)

At approximately 3–15 feet landing gear height AGL, depending upon the helicopter being used, begin to level the helicopter with forward cyclic control. Avoid excessive nose-high, tail-low attitude below 10 feet. Just prior to achieving level attitude, with the nose still slightly up, coordinate upward collective pitch control with an increase in the throttle to join the needles at operating rpm. The throttle and collective pitch must be coordinated properly.

If the throttle is increased too fast or too much, an engine overspeed can occur; if throttle is increased too slowly or too little in proportion to the increase in collective pitch, a loss of rotor rpm results. Use sufficient collective pitch to stop the descent, but keep in mind that the collective pitch application must be gradual to allow for engine response. Coordinate proper antitorque pedal pressure to maintain heading. When a landing is to be made following the power recovery, bring the helicopter to a hover and then descend to a landing.

In nearly all helicopters, when practicing autorotations with power recovery, the throttle should be at the flight setting at the beginning of the flare. As the rotor disk begins to dissipate its energy, the engine is up to speed as the needles join when the rotor decreases into the normal flight rpm.

Helicopters that do not have the throttle control located on the collective are generally exceptions to basic technique and require some additional prudence. The autorotation should be initiated with the power levers left in the “flight,” or normal, position. If a full touchdown is to be practiced, it is common technique to move the power levers to the idle position once the landing area can safely be reached. In most helicopters, the pilot is fully committed at that point to make a power-off landing. However, it may be possible to make a power recovery prior to passing through 100 feet AGL if the powerplant can recover within that time period and the instructor is very proficient. The pilot should comply with the RFM instructions in all cases.

When practicing autorotations to a power recovery, the differences between reciprocating engines and turbines may be profound. The reciprocating powerplant generally responds very quickly to power changes, especially power increases. Some turbines have delay times depending on the type of fuel control or governing system installed. Any reciprocating engine needing turbocharged boost to develop rated horse power may have significant delays to demands for increased power, such as in the power recovery. Power recovery in those helicopters with slower engine response times must have the engines begin to develop enough power to rejoin the needles by approximately 100 feet AGL.

If a go-around is to be made, the cyclic control should be moved forward to resume forward flight. In transition from a practice autorotation to a go-around, exercise caution to avoid an altitude-airspeed combination that would place the helicopter in an unsafe area of its height/velocity diagram.

This is one of the most difficult maneuvers to perform due to the concentration needed when transitioning from powered flight to autorotation and then back again to powered flight. For helicopters equipped with the power control on the collective, engine power must be brought from flight power to idle power and then back to a flight power setting. A delay during any of these transitions can seriously affect rotor rpm placing the helicopter in a situation that cannot be recovered.

The cyclic must be adjusted to maintain the required airspeed without power, and then used for the deceleration flare, followed by the transition to level hovering flight. Additionally, the cyclic must be adjusted to remove the compensation for translating tendency. The tail rotor is no longer needed to produce antitorque thrust until almost maximum power is applied to the rotor disk for hovering flight, when the tail rotor must again compensate for the main rotor torque, which also demands compensation for the tail rotor thrust and translating tendency.

The pedals must be adjusted from a powered flight anti-torque trim setting to the opposite trim setting to compensate for transmission drag and any unneeded vertical fin thrust countering the now nonexistent torque and then reset to compensate for the high power required for hovering flight.

All of the above must be accomplished during the 23 seconds of the autorotation, and the quick, precise control inputs must be made in the last 5 seconds of the maneuver.

Common Errors

1. Initiating recovery too late, which requires a rapid application of controls and results in overcontrolling.
2. Failure to obtain and maintain a level attitude near the surface.
3. Failure to coordinate throttle and collective pitch properly, which results in either an engine overspeed or a loss of rotor rpm.
4. Failure to coordinate proper antitorque pedal with the increase in power.
5. Late engine power engagement causing excessive temperature or torque, or rpm drop.
6. Failure to go around if not within limits and specified criteria for safe autorotation.

Practicing Power Failure in a Hover

Power failure in a hover, also called hovering autorotation, is practiced so that a pilot can automatically make the correct response when confronted with engine stoppage or certain other emergencies while hovering. The techniques discussed in this section are for helicopters with a counterclockwise rotor disk and an antitorque rotor.

Technique (How to Practice)

To practice hovering autorotation, establish a normal hovering height (approximately 2–3 feet) for the particular helicopter being used, considering load and atmospheric conditions. Keep the helicopter headed into the wind and hold maximum allowable rpm.

To simulate a power failure, firmly roll the throttle to the engine idle position. This disengages the driving force of the engine from the rotor, thus eliminating torque effect. As the throttle is closed, apply proper antitorque pedal to maintain heading. Usually, a slight amount of right cyclic control is necessary to keep the helicopter from drifting to the left, to compensate for the loss of tail rotor thrust. However, use cyclic control, as required, to ensure a vertical descent and a level attitude. Do not adjust the collective on entry.

Helicopters with low inertia rotor disks settle immediately. Keep a level attitude and ensure a vertical descent with cyclic control while maintaining heading with the pedals. Any lateral movement must be avoided to prevent dynamic rollover. As rotor rpm decays, cyclic response decreases, so compensation for the winds will require more cyclic input. At approximately 1 foot AGL, apply upward collective control, as necessary, to slow the descent and cushion the landing without arresting the rate of descent above the surface. Usually, the full amount of collective is required just as the landing gear touches the surface. As upward collective control is applied, the throttle must be held in the idle detent position to prevent the engine from re-engaging. The idle detention position is a ridged stop position between idle and off in which the idle release button snaps into, prevent accidental throttle off.

Helicopters with high-inertia rotor disks settle more slowly after the throttle is closed. In this case, when the helicopter has settled to approximately 1 foot AGL, apply upward collective control while holding the throttle in the idle detent position to slow the descent and cushion the landing. The timing of collective control application and the rate at which it is applied depend upon the particular helicopter being used, its gross weight, and the existing atmospheric conditions. Cyclic control is used to maintain a level attitude and to ensure a vertical descent. Maintain heading with antitorque pedals.

When the weight of the helicopter is entirely resting on the landing gear, cease application of upward collective. When the helicopter has come to a complete stop, lower the collective pitch to the full-down position.

The timing of the collective movement is a very important consideration. If it is applied too soon, the remaining rpm may not be sufficient to make a soft landing. On the other hand, if it is applied too late, surface contact may be made before sufficient blade pitch is available to cushion the landing. The collective must not be used to hold the helicopter off the surface, causing a blade stall. Low rotor rpm and ensuing blade stall can result in a total loss of rotor lift, allowing the helicopter to fall to the surface and possibly resulting in blade strikes to the tail boom and other airframe damage such as landing gear damage, transmission mount deformation, and fuselage cracking.

Common Errors

1. Failure to use sufficient proper antitorque pedal when power is reduced.
2. Failure to stop all sideward or backward movement prior to touchdown.
3. Failure to apply up-collective pitch properly, resulting in a hard touchdown.

4. Failure to touch down in a level attitude.
5. Failure to roll the throttle completely to idle.
6. Failure to hover at a safe altitude for the helicopter type, atmospheric conditions, and the level of training/proficiency of the pilot.
7. Failure to go around if not within limits and specified criteria for safe autorotation.

Vortex Ring State

Vortex ring state (formerly referenced as settling-with-power) describes an aerodynamic condition in which a helicopter may be in a vertical descent with 20 percent up to maximum power applied, and little or no climb performance. The previously used term settling-with-power came from the fact that the helicopter keeps settling even though full engine power is applied.

In a normal out-of-ground-effect (OGE) hover, the helicopter is able to remain stationary by propelling a large mass of air down through the main rotor. Some of the air is recirculated near the tips of the blades, curling up from the bottom of the rotor disk and rejoining the air entering the rotor from the top. This phenomenon is common to all airfoils and is known as tip vortices. Tip vortices generate drag and degrade airfoil efficiency. As long as the tip vortices are small, their only effect is a small loss in rotor efficiency. However, when the helicopter begins to descend vertically, it settles into its own downwash, which greatly enlarges the tip vortices. In this vortex ring state, most of the power developed by the engine is wasted in circulating the air in a doughnut pattern around the rotor.

In addition, the helicopter may descend at a rate that exceeds the normal downward induced-flow rate of the inner blade sections. As a result, the airflow of the inner blade sections is upward relative to the disk. This produces a secondary vortex ring in addition to the normal tip vortices. The secondary vortex ring is generated about the point on the blade where the airflow changes from up to down. The result is an unsteady turbulent flow over a large area of the disk. Rotor efficiency is lost even though power is still being supplied from the engine. [Figure 11-3]

A fully developed vortex ring state is characterized by an unstable condition in which the helicopter experiences uncommanded pitch and roll oscillations, has little or no collective authority, and achieves a descent rate that may approach 6,000 feet per minute (fpm) if allowed to develop.

A vortex ring state may be entered during any maneuver that places the main rotor in a condition of descending in a column of disturbed air and low forward airspeed. Airspeeds

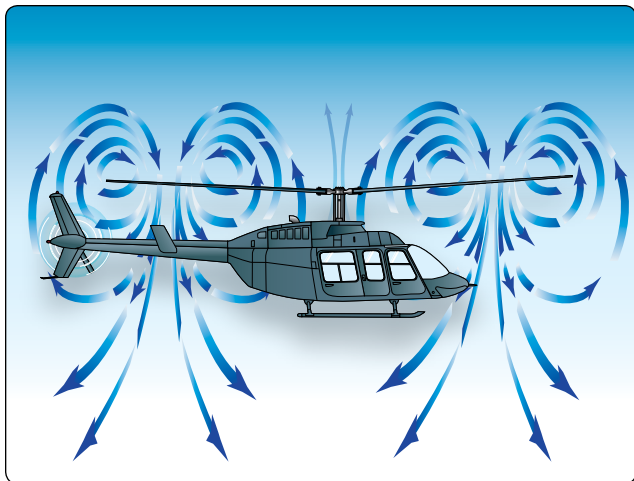


Figure 11-3. *Vortex ring state.*

that are below translational lift airspeeds are within this region of susceptibility to vortex ring state aerodynamics. This condition is sometimes seen during quick-stop type maneuvers or during recovery from autorotation.

The following combination of conditions is likely to cause settling in a vortex ring state in any helicopter:

1. A vertical or nearly vertical descent of at least 300 fpm. (Actual critical rate depends on the gross weight, rpm, density altitude, and other pertinent factors.)
2. The rotor disk must be using some of the available engine power (20–100 percent).
3. The horizontal velocity must be slower than effective translational lift.

Situations that are conducive to a vortex ring state condition are attempting to hover OGE without maintaining precise altitude control, and approaches, especially steep approaches, with a tailwind component.

When recovering from a vortex ring state condition, the pilot tends first to try to stop the descent by increasing collective pitch. However, this only results in increasing the stalled area of the rotor, thereby increasing the rate of descent. Since inboard portions of the blades are stalled, cyclic control may be limited. The traditional recovery is accomplished by increasing airspeed, and/or partially lowering collective to exit the vortex. In most helicopters, lateral cyclic thrust combined with an increase in power and lateral antitorque thrust will produce the quickest exit from the hazard. This technique, known as the Vuichard Recovery (named after the Swiss examiner from the Federal Office of Civil Aviation who developed it) recovers by eliminating the descent rate as opposed to exiting the vortex. If the vortex ring state and the corresponding descent rate is allowed to progress to what is

called the windmill brake state, the point where the airflow is completely up through the rotor, the only recovery may be an autorotation.

Tandem rotor helicopters should maneuver laterally to achieve clean air in both rotors at the same time.

For vortex ring state demonstrations and training in recognition and recovery should be performed from a safe altitude to allow recovery no less than 1000 feet AGL or the manufacturer's recommended altitude, whichever is higher.

To enter the maneuver, come to an OGE hover, maintaining little or no airspeed (any direction), decrease collective to begin a vertical descent, and as the turbulence begins, increase collective. Then allow the sink rate to increase to 300 fpm or more as the attitude is adjusted to obtain airspeed of less than 10 knots. When the aircraft begins to shudder, the application of additional up collective increases the vibration and sink rate. As the power is increased, the rate of sink of the aircraft in the column of air will increase.

If altitude is sufficient, some time can be spent in the vortices, to enable the pilot to develop a healthy knowledge of the maneuver. However, helicopter pilots would normally initiate recovery at the first indication of vortex ring state. Recovery should be initiated at the first sign of vortex ring state by applying forward cyclic to increase airspeed and/ or simultaneously reducing collective. The recovery is complete when the aircraft passes through effective translational lift and a normal climb is established.

Common Errors—Traditional Recovery

1. Too much lateral speed for entry into vortex ring state.
2. Excessive decrease of collective.

Common Errors—Vuichard Recovery

1. Excessive lateral cyclic
2. Failure to maintain heading

Retreating Blade Stall

In forward flight, the relative airflow through the main rotor disk is different on the advancing and retreating side. The relative airflow over the advancing side is higher due to the forward speed of the helicopter, while the relative airflow on the retreating side is lower. This dissymmetry of lift increases as forward speed increases.

To generate the same amount of lift across the rotor disk, the advancing blade flaps up while the retreating blade flaps down. This causes the AOA to decrease on the advancing

blade, which reduces lift, and increase on the retreating blade, which increases lift. At some point as the forward speed increases, the low blade speed on the retreating blade, and its high AOA cause a stall and loss of lift.

Retreating blade stall is a factor in limiting a helicopter's never-exceed speed (V_{NE}) and its development can be felt by a low frequency vibration, pitching up of the nose, and a roll in the direction of the retreating blade. High weight, low rotor rpm, high density altitude, turbulence and/or steep, abrupt turns are all conducive to retreating blade stall at high forward airspeeds. As altitude is increased, higher blade angles are required to maintain lift at a given airspeed. Thus, retreating blade stall is encountered at a lower forward airspeed at altitude. Most manufacturers publish charts and graphs showing a V_{NE} decrease with altitude.

When recovering from a retreating blade stall condition caused by high airspeed, moving the cyclic aft only worsens the stall as aft cyclic produces a flare effect, thus increasing the AOA. Pushing forward on the cyclic also deepens the stall as the AOA on the retreating blade is increased. While the first step in a proper recovery is usually to reduce collective, RBS should be evaluated in light of the relevant factors discussed in the previous paragraph and addressed accordingly. For example, if a pilot at high weight and high DA is about to conduct a high reconnaissance prior to a confined area operation where rolling into a steep turn causes onset of RBS, the recovery is to roll out of the turn. If the cause is low rotor rpm, then increase the rpm.

Common Errors

1. Failure to recognize the combination of contributing factors leading to retreating blade stall.
2. Failure to compute V_{NE} limits for altitudes to be flown.

Ground Resonance

Helicopters with articulating rotors (usually designs with three or more main rotor blades) are subject to ground resonance, a destructive vibration phenomenon that occurs at certain rotor speeds when the helicopter is on the ground. Ground resonance is a mechanical design issue that results from the helicopter's airframe having a natural frequency that can be intensified by an out-of-balance rotor. The unbalanced rotor disk vibrates at the same frequency (or multiple thereof) of the airframe's resonant frequency, and the harmonic oscillation increases because the engine is adding power to the system, increasing the magnitude (amplitude) of the vibrations until the structure or structures fail. This condition can cause a helicopter to self-destruct in a matter of seconds.

Hard contact with the ground on one corner (and usually with wheel-type landing gear) can send a shockwave to the main rotor head, resulting in the blades of a three-blade rotor disk moving from their normal 120° relationship to each other. This movement occurs along the drag hinge and could result in something like 122° , 122° , and 116° between blades. [Figure 11-4] When another part of the landing gear strikes the surface, the unbalanced condition could be further aggravated.

If the rpm is low, the only corrective action to stop ground resonance is to close the throttle immediately and fully lower the collective to place the blades in low pitch. If the rpm is in the normal operating range, fly the helicopter off the ground, and allow the blades to rephase themselves automatically. Then, make a normal touchdown. If a pilot lifts off and allows the helicopter to firmly re-contact the surface before the blades are realigned, a second shock could move the blades again and aggravate the already unbalanced condition. This could lead to a violent, uncontrollable oscillation.

This situation does not occur in rigid or semi-rigid rotor disks because there is no drag hinge. In addition, skid-type landing gear is not as prone to ground resonance as wheel-type landing gear, since the rubber tires' resonant frequency typically can match that of the spinning rotor, unlike the condition of a rigid landing gear.

Dynamic Rollover

A helicopter is susceptible to a lateral rolling tendency, called dynamic rollover, when it is in contact with the surface



Figure 11-4. Ground resonance.

during takeoffs or landings. For dynamic rollover to occur, some factor must first cause the helicopter to roll or pivot around a skid or landing gear wheel, until its critical rollover angle is reached. The angle at which dynamic rollover occurs will vary based on helicopter type. Then, beyond this point, main rotor thrust continues the roll and recovery is impossible. After this angle is achieved, the cyclic does not have sufficient range of control to eliminate the thrust component and convert it to lift. If the critical rollover angle is exceeded, the helicopter rolls on its side regardless of the cyclic corrections made.

Dynamic rollover begins when the helicopter starts to pivot laterally around its skid or wheel. For dynamic rollover to occur the following three factors must be present:

1. A rolling moment
2. A pivot point other than the helicopter's normal CG
3. Thrust greater than weight

This can occur for a variety of reasons, including the failure to remove a tie down or skid-securing device, or if the skid or wheel contacts a fixed object while hovering sideward, or if the gear is stuck in ice, soft asphalt, or mud. Dynamic rollover may also occur if you use an improper landing or takeoff technique or while performing slope operations. Whatever the cause, dynamic rollover is possible if not using the proper corrective technique.

Once started, dynamic rollover cannot be stopped by application of opposite cyclic control alone. For example, the right skid contacts an object and becomes the pivot point while the helicopter starts rolling to the right. Even with full left cyclic applied, the main rotor thrust vector and its moment follows the aircraft as it continues rolling to the right. Quickly reducing collective pitch is the most effective way to stop dynamic rollover from developing. Dynamic rollover can occur with any type of landing gear and all types of rotor disks.

It is important to remember rotor blades have a limited range of movement. If the tilt or roll of the helicopter exceeds that range ($5-8^\circ$), the controls (cyclic) can no longer command a vertical lift component and the thrust or lift becomes a lateral force that rolls the helicopter over. When limited rotor blade movement is coupled with the fact that most of a helicopter's weight is high in the airframe, another element of risk is added to an already slightly unstable center of gravity. Pilots must remember that in order to remove thrust, the collective must be lowered as this is the only recovery technique available.

Critical Conditions

Certain conditions reduce the critical rollover angle, thus increasing the possibility for dynamic rollover and reducing

the chance for recovery. The rate of rolling motion is also a consideration because, as the roll rate increases, there is a reduction of the critical rollover angle at which recovery is still possible. Other critical conditions include operating at high gross weights with thrust (lift) approximately equal to the weight.

Refer to *Figure 11-5*. The following conditions are most critical for helicopters with counterclockwise rotor rotation:

1. Right side skid or landing wheel down, since translating tendency adds to the rollover force.
2. Right lateral center of gravity (CG).
3. Crosswinds from the left.
4. Left yaw inputs.

For helicopters with clockwise rotor rotation, the opposite conditions would be true.

Cyclic Trim

When maneuvering with one skid or wheel on the ground, care must be taken to keep the helicopter cyclic control carefully adjusted. For example, if a slow takeoff is attempted and the cyclic is not positioned and adjusted to account for translating tendency, the critical recovery angle may be exceeded in less than two seconds. Control can be maintained if the pilot maintains proper cyclic position and does not allow the helicopter's roll and pitch rates to become too great. Fly the helicopter into the air smoothly while keeping movements of pitch, roll, and yaw small; do not allow any abrupt cyclic pressures.

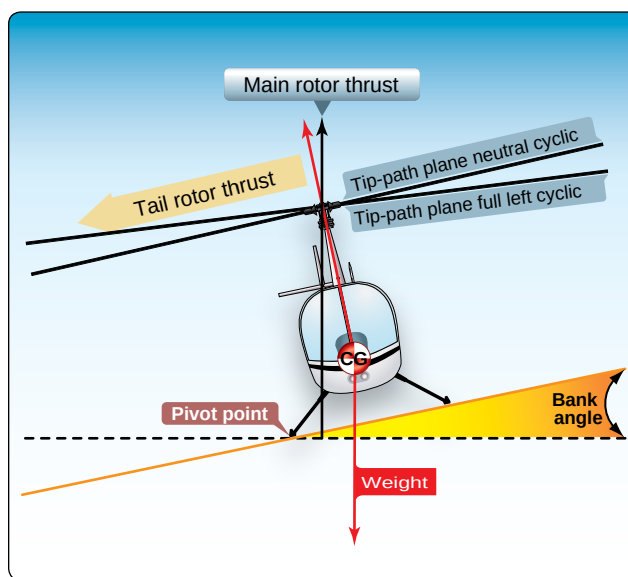


Figure 11-5. Forces acting on a helicopter with right skid on the ground.

Normal Takeoffs and Landings

Dynamic rollover is possible even during normal takeoffs and landings on relatively level ground, if one wheel or skid is on the ground and thrust (lift) is approximately equal to the weight of the helicopter. If the takeoff or landing is not performed properly, a roll rate could develop around the wheel or skid that is on the ground. When taking off or landing, perform the maneuver smoothly and carefully adjust the cyclic so that no pitch or roll movement rates build up, especially the roll rate. If the bank angle starts to increase to an angle of approximately $5-8^\circ$, and full corrective cyclic does not reduce the angle, the collective should be reduced to diminish the unstable rolling condition. Excessive bank angles can also be caused by landing gear caught in a tie down strap, or a tie down strap still attached to one side of the helicopter. Lateral loading imbalance (usually outside published limits) is another contributing factor.

Slope Takeoffs and Landings

During slope operations, excessive application of cyclic control into the slope, together with excessive collective pitch control, can result in the downslope skid or landing wheel rising sufficiently to exceed lateral cyclic control limits, and an upslope rolling motion can occur. [Figure 11-6]

When performing slope takeoff and landing maneuvers, follow the published procedures and keep the roll rates small. Slowly raise the downslope skid or wheel to bring the helicopter level, and then lift off. During landing, first touch down on the upslope skid or wheel, then slowly lower the downslope skid or wheel using combined movements of cyclic and collective. If the helicopter rolls approximately $5-8^\circ$ to the upslope side, decrease collective to correct the bank angle and return to level attitude, then start the landing procedure again.

Use of Collective

The collective is more effective in controlling the rolling motion than lateral cyclic, because it reduces the main rotor

thrust (lift). A smooth, moderate collective reduction, at a rate of less than approximately full up to full down in two seconds, may be adequate to stop the rolling motion. Take care, therefore, not to dump collective at an excessively high rate, as this may cause a main rotor blade to strike the fuselage. Additionally, if the helicopter is on a slope and the roll starts toward the upslope side, reducing collective too fast may create a high roll rate in the opposite direction. When the upslope skid or wheel hits the ground, the dynamics of the motion can cause the helicopter to bounce off the upslope skid or wheel, and the inertia can cause the helicopter to roll about the downslope ground contact point and over on its side. [Figure 11-7]

Under normal conditions on a slope, the collective should not be pulled suddenly to get airborne because a large and abrupt rolling moment in the opposite direction could occur. Excessive application of collective can result in the upslope skid or wheel rising sufficiently to exceed lateral cyclic control limits. This movement may be uncontrollable. If the helicopter develops a roll rate with one skid or wheel on the ground, the helicopter can roll over on its side.

Precautions

To help avoid dynamic rollover:

1. Always practice hovering autorotations into the wind, and be wary when the wind is gusty or greater than 10 knots.
2. Use extreme caution when hovering close to fences, sprinklers, bushes, runway/taxi lights, tiedown cables, deck nets, or other obstacles that could catch a skid or wheel. Aircraft parked on hot asphalt overnight might find the landing gear sunk in and stuck as the ramp cooled during the evening.

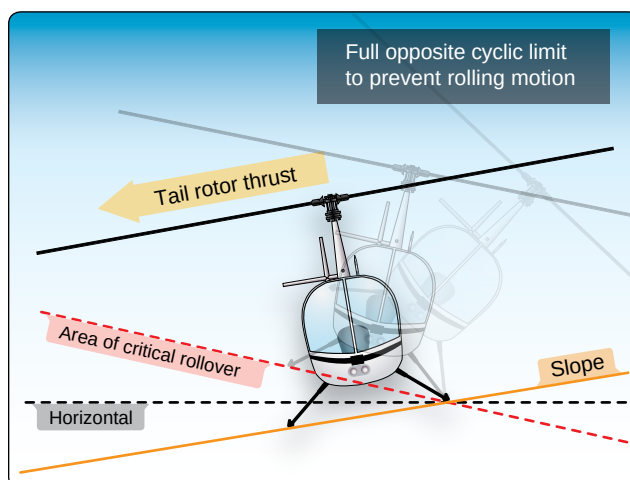


Figure 11-6. Upslope rolling motion.

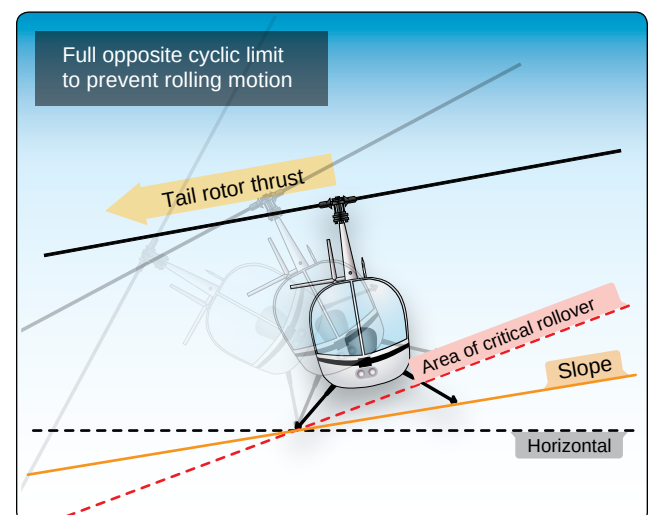


Figure 11-7. Downslope rolling motion.

3. Always use a two-step lift-off. Pull in just enough collective pitch control to be light on the skids or landing wheels and feel for equilibrium, then gently lift the helicopter into the air. 4. Hover high enough to have adequate skid or landing wheel clearance from any obstacles when practicing hovering maneuvers close to the ground, especially when practicing sideways or rearward flight.
5. Remember that when the wind is coming from the upslope direction, less lateral cyclic control is available.
6. Avoid tailwind conditions when conducting slope operations.
7. Remember that less lateral cyclic control is available due to the translating tendency of the tail rotor when the left skid or landing wheel is upslope. (This is true for counterclockwise rotor disks.)
8. Keep in mind that the lateral cyclic requirement changes when passengers or cargo are loaded or unloaded.
9. Be aware that if the helicopter utilizes interconnecting fuel lines that allow fuel to automatically transfer from one side of the helicopter to the other, the gravitational flow of fuel to the downslope tank could change the CG, resulting in a different amount of cyclic control application to obtain the same lateral result.
10. Do not allow the cyclic limits to be reached. If the cyclic control limit is reached, further lowering of the collective may cause mast bumping. If this occurs, return to a hover and select a landing point with a lesser degree of slope.
11. During a takeoff from a slope, begin by leveling the main rotor disk with the horizon or very slightly into the slope to ensure vertical lift and only enough lateral thrust to prevent sliding on the slope. If the upslope skid or wheel starts to leave the ground before the downslope skid or wheel, smoothly and gently lower the collective and check to see if the downslope skid or wheel is caught on something. Under these conditions, vertical ascent is the only acceptable method of lift-off.
12. Be aware that dynamic rollover can be experienced during flight operations on a floating platform if the platform is pitching/rolling while attempting to land or takeoff. Generally, the pilot operating on floating platforms (barges, ships, etc.) observes a cycle of seven during which the waves increase and then decrease to a minimum. It is that time of minimum wave motion that the pilot needs to use for the moment of landing or takeoff on floating platforms. Pilots operating from floating platforms should also exercise great caution concerning cranes, masts, nearby boats (tugs) and nets.

Low-G Conditions and Mast Bumping

“G” is an abbreviation for acceleration due to the earth’s gravity. A person standing on the ground or sitting in an aircraft in level flight is experiencing one G. An aircraft in a tight, banked turn with the pilot being pressed into the seat is experiencing more than one G or high-G conditions. A person beginning a downward ride in an elevator or riding down a steep track on a roller coaster is experiencing less than one G or low-G conditions. The best way for a pilot to recognize low G is a weightless feeling similar to the start of a downward elevator ride.

Helicopters rely on positive G to provide much or all of their response to pilot control inputs. The pilot uses the cyclic to tilt the rotor disk, and, at one G, the rotor is producing thrust equal to aircraft weight. The tilting of the thrust vector provides a moment about the center of gravity to pitch or roll the fuselage. In a low-G condition, the thrust and consequently the control authority are greatly reduced.

Although their control ability is reduced, multi-bladed (three or more blades) helicopters can generate some moment about the fuselage independent of thrust due to the rotor hub design with the blade attachment offset from the center of rotation. However, helicopters with two-bladed teetering rotors rely entirely on the tilt of the thrust vector for control. Therefore, low-G conditions can be catastrophic for two-bladed helicopters.

At lower speeds, such as initiation of a takeoff from hover or the traditional recovery from vortex ring state, forward cyclic maneuvers do not cause low G and are safe to perform. However, an abrupt forward cyclic input or pushover in a two-bladed helicopter can be dangerous and must be avoided, particularly at higher speeds. During a pushover from moderate or high airspeed, as the helicopter noses over, it enters a low-G condition. Thrust is reduced, and the pilot has lost control of fuselage attitude but may not immediately realize it. Tail rotor thrust or other aerodynamic factors will often induce a roll. The pilot still has control of the rotor disk, and may instinctively try to correct the roll, but the fuselage does not respond due to the lack of thrust. If the fuselage is rolling right, and the pilot puts in left cyclic to correct, the combination of fuselage angle to the right and rotor disk angle to the left becomes quite large and may exceed the clearances built into the rotor hub. This results in the hub contacting the rotor mast, which is known as mast bumping. [Figure 11-8] Low-G mast bumping has been the cause of numerous military and civilian fatal accidents. It was initially encountered during nap-of-the-earth flying, a very low-altitude tactical flight technique used by the military where

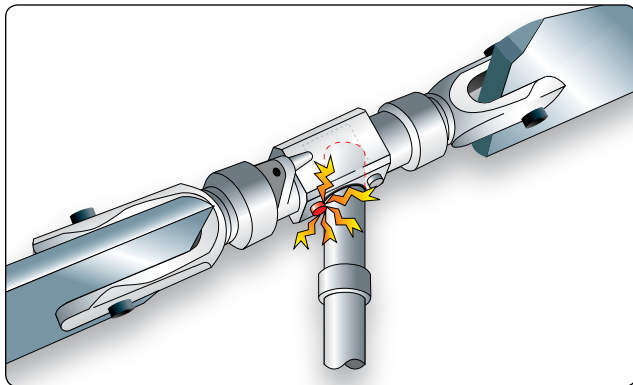


Figure 11-8. Result of improper corrective action in a low-G condition.

the aircraft flies following the contours of the geographical terrain. The accident sequence may be extremely rapid, and the energy and inertia in the rotor system can sever the mast or allow rotor blades to strike the tail or other portions of the helicopter.

Turbulence, especially severe downdrafts, can also cause a low-G condition and, when combined with high airspeed, may lead to mast bumping. Typically, helicopters handle turbulence better than a light airplane due to smaller surface area of the rotor blades. During flight in turbulence, momentary excursions in airspeed, altitude, and attitude are to be expected. Pilots should respond with smooth, gentle control inputs and avoid overcontrolling. Most importantly, pilots should slow down, as mast bumping is less likely at lower airspeeds.

Pilots can avoid mast bumping accidents as follows:

- Avoid abrupt forward cyclic inputs in two-bladed helicopters. Airplane pilots may find this a difficult habit to break because pushing the nose down is an accepted collision avoidance maneuver in an airplane. Helicopter pilots would accomplish the same rapid descent by lowering the collective, and airplane pilots should train to make this instinctual.
- Recognize the weightless feeling associated with the onset of low G and quickly take corrective action before the situation becomes critical.
- Recognize that uncommanded right roll for helicopters with main rotors which rotate counter-clockwise when viewed from above indicates that loss of control is imminent, and immediate corrective action must be taken.
- Recover from a low-G situation by first gently applying aft cyclic to restore normal G before

attempting to correct any roll.

- If turbulence is expected or encountered, reduce power and use a slower than normal cruise speed. Turbulence (where high rotor flapping angles are already present), and higher airspeeds (where the controls are more sensitive) both increase susceptibility to low-G conditions.
- Use a flight simulator to learn to recognize and experience low G conditions that result in mast bumping, its correct recovery technique, and the consequences of using incorrect recovery actions. Refer to Chapter 14, Simulation.

Multi-bladed rotors may experience a phenomenon similar to mast bumping known as droop stop pounding if flapping clearances are exceeded, but because they retain some control authority at low G, occurrences are less common than for teetering rotors.

Low Rotor RPM and Rotor Stall

Rotor rpm is a critically important parameter for all helicopter operations. Just as airplanes will not fly below a certain airspeed, helicopters will not fly below a certain rotor rpm. Safe rotor rpm ranges are marked on the helicopter's tachometer and specified in the RFM. If the pilot allows the rotor rpm to fall below the safe operating range, the helicopter is in a low rpm situation. If the rotor rpm continues to fall, the rotor will eventually stall.

Rotor stall should not be confused with retreating blade stall, which occurs at high forward speeds and over a small portion of the retreating blade tip. Retreating blade stall causes vibration and control problems, but the rotor is still very capable of providing sufficient lift to support the weight of the helicopter. Rotor stall, however, can occur at any airspeed, and the rotor quickly stops producing enough lift to support the helicopter, causing it to lose lift and descend rapidly.

Rotor stall is very similar to the stall of an airplane wing at low airspeeds. The airplane wing relies on airspeed to produce the required airflow over the wing, whereas the helicopter relies on rotor rpm. As the airspeed of the airplane decreases or the speed of the helicopter rotor slows down, the AOA of the wing/rotor blade must be increased to support the weight of the aircraft. At a critical angle (about 15°), the airflow over the wing or the rotor blade will separate and stall, causing a sudden loss of lift and increase in drag (refer to Chapter 2, Aerodynamics of Flight). An airplane pilot recovers from a stall by lowering the nose to reduce the AOA and adding power to restore normal airflow over the wing. However, the falling helicopter is experiencing upward

airflow through the rotor disk, and the resulting AOA is so high that even full down collective will not restore normal airflow. In the helicopter when the rotor stalls, it does not do so symmetrically because any forward airspeed will produce a higher airflow on the advancing side than on the retreating side. This causes the retreating blade to stall first, and its weight makes it descend as it moves aft while the advancing blade is climbing as it goes forward. The resulting low aft blade and high forward blade become a rapid aft tilting of the rotor disc sometimes referred to as rotor “blow back” or “flap back.” As the helicopter begins to descend, the upward flow of air acting on the bottom surfaces of the tail boom and any horizontal stabilizers tend to pitch the aircraft nose down. These two effects, combined with any aft cyclic by the pilot attempting to keep the aircraft level, allow the rotor blades to blow back and contact the tail boom, in some cases actually severing the tail boom. Since the tail rotor is geared to the main rotor, in many helicopters the loss of main rotor rpm also causes a significant loss of tail rotor thrust and a corresponding loss of directional control.

Rotor stalls in helicopters are not recoverable. At low altitude, rotor stall will result in an accident with significant damage to the helicopter, and at altitudes above approximately 50 feet the accident will likely be fatal. Consequently, early recognition of the low rotor rpm condition and proper recovery technique is imperative.

Low rotor rpm can occur during power-off and power-on operations. During power-off flight, a low rpm situation can be caused by the failure to quickly lower the collective after an engine failure or by raising the collective at too great a height above ground at the bottom of an autorotation. However, more common are power-on rotor stall accidents. These occur when the engine is operating normally but the pilot demands more power than is available by pulling up too much on the collective. Known as “overpitching,” this can easily occur at higher density altitudes where the engine is already producing its maximum horsepower and the pilot raises the collective. The corresponding increased AOA of the blades requires more engine horsepower to maintain the speed of the blades; however, the engine cannot produce any additional horsepower, so the speed of the blades decreases. A similar situation can occur with a heavily loaded helicopter taking off from a confined area. Other causes of a power-on low rotor rpm condition include the pilot rolling the throttle the wrong way in helicopters not equipped with a governor or a governor failure in helicopters so equipped.

As the rpm decreases, the amount of horsepower the engine can produce also decreases. Engine horsepower is directly proportional to its rpm, so a 10 percent loss in rpm due to overpitching, or one of the other scenarios above, will

result in a 10 percent loss in the engine’s ability to produce horsepower, making recovery even slower and more difficult than it would otherwise be. With less power from the engine and less lift from the decaying rotor rpm, the helicopter will start to settle. If the pilot raises the collective to stop the settling, the situation will feed upon itself rapidly leading to rotor stall.

There are a number of ways the pilot can recognize the low rotor rpm situation. Visually, the pilot can not only see the rotor rpm indicator decrease but also the change in torque will produce a yaw; there will also be a noticeable decrease in engine noise, and at higher airspeeds or in turns, an increase in vibration. Many helicopters have a low rpm warning system that alerts the pilot to the low rotor rpm condition.

To recover from the low rotor rpm condition the pilot must simultaneously lower the collective, increase throttle if available and apply aft cyclic to maintain a level attitude. At higher airspeeds, additional aft cyclic may be used to help recover lost rpm. Recovery should be accomplished immediately before investigating the problem and must be practiced to become a conditioned reflex.

System Malfunctions

By following the manufacturer’s recommendations regarding operating limits and procedures and periodic maintenance and inspections, many system and equipment failures can be eliminated. Certain malfunctions or failures can be traced to some error on the part of the pilot; therefore, appropriate flying techniques and use of threat and error management may help to prevent an emergency

Antitorque System Failure

Antitorque failure usually falls into one of two categories. One is failure of the power drive portion of the tail rotor disk resulting in a complete loss of antitorque. The other category covers mechanical control failures prohibiting the pilot from changing or controlling tail rotor thrust even though the tail rotor may still be providing antitorque thrust.

Tail rotor drive system failures include driveshaft failures, tail rotor gearbox failures, or a complete loss of the tail rotor itself. In any of these cases, the loss of antitorque normally results in an immediate spinning of the helicopter’s nose. The helicopter spins to the right in a counterclockwise rotor disk and to the left in a clockwise system. This discussion is for a helicopter with a counterclockwise rotor disk. The severity of the spin is proportionate to the amount of power being used and the airspeed. An antitorque failure with a high-power setting at a low airspeed results in a severe spinning to the

right. At low power settings and high airspeeds, the spin is less severe. High airspeeds tend to streamline the helicopter and keep it from spinning.

If a tail rotor failure occurs, power must be reduced in order to reduce main rotor torque. The techniques differ depending on whether the helicopter is in flight or in a hover, but ultimately require an autorotation. If a complete tail rotor failure occurs while hovering, enter a hovering autorotation by rolling off the throttle. If the failure occurs in forward flight, enter a normal autorotation by lowering the collective and rolling off the throttle. If the helicopter has enough forward airspeed (close to cruising speed) when the failure occurs, and depending on the helicopter design, the vertical stabilizer may provide enough directional control to allow the pilot to maneuver the helicopter to a more desirable landing sight. Applying slight cyclic control opposite the direction of yaw compensates for some of the yaw. This helps in directional control, but also increases drag. Care must be taken not to lose too much forward airspeed because the streamlining effect diminishes as airspeed is reduced. Also, more altitude is required to accelerate to the correct airspeed if an autorotation is entered at a low airspeed.

The throttle or power lever on some helicopters is not located on the collective and readily available. Faced with the loss of antitorque, the pilot of these models may need to achieve forward flight and let the vertical fin stop the yawing rotation. With speed and altitude, the pilot will have the time to set up for an autorotative approach and set the power control to idle or off as the situation dictates. At low altitudes, the pilot may not be able to reduce the power setting and enter the autorotation before impact.

A mechanical control failure limits or prevents control of tail rotor thrust and is usually caused by a stuck or broken control rod or cable. While the tail rotor is still producing antitorque thrust, it cannot be controlled by the pilot. The amount of antitorque depends on the position at which the controls jam or fail. Once again, the techniques differ depending on the amount of tail rotor thrust, but an autorotation is generally not required.

The specific manufacturer's procedures should always be followed. The following is a generalized description of procedures when more specific procedures are not provided.

Landing—Stuck Left Pedal

A stuck left pedal (high power setting), which might be experienced during takeoff or climb conditions, results in the left yaw of the helicopter nose when power is reduced. Rolling off the throttle and entering an autorotation only makes matters worse. The landing profile for a stuck left

pedal is best described as a normal-to-steep approach angle to arrive approximately 2–3 feet landing gear height above the intended landing area as translational lift is lost. The steeper angle allows for a lower power setting during the approach and ensures that the nose remains to the right.

Upon reaching the intended touchdown area and at the appropriate landing gear height, increase the collective smoothly to align the nose with the landing direction and cushion the landing. A small amount of forward cyclic is helpful to stop the nose from continuing to the right and directs the aircraft forward and down to the surface. In certain wind conditions, the nose of the helicopter may remain to the left with zero to near zero groundspeed above the intended touchdown point. If the helicopter is not turning, simply lower the helicopter to the surface. If the nose of the helicopter is turning to the right and continues beyond the landing heading, roll the throttle toward flight idle, which is the amount necessary to stop the turn while landing. Flight idle is an engine rpm in flight at a given altitude with the throttle set to the minimum, or idle, position. The flight idling rpm typically increase with an increase in altitude. If the helicopter is beginning to turn left, the pilot should be able to make the landing prior to the turn rate becoming excessive. However, if the turn rate begins to increase prior to the landing, simply add power to make a go-around and return for another landing.

Landing—Stuck Neutral or Right Pedal

The landing profile for a stuck neutral or a stuck right pedal is a low-power approach terminating with a running or roll-on landing. The approach profile can best be described as a shallow to normal approach angle to arrive approximately 2–3 feet landing gear height above the intended landing area with a minimum airspeed for directional control. The minimum airspeed is one that keeps the nose from continuing to yaw to the right.

Upon reaching the intended touchdown area and at the appropriate landing gear height, reduce the throttle as necessary to overcome the yaw effect if the nose of the helicopter remains to the right of the landing heading. The amount of throttle reduction will vary based on power applied and winds. The higher the power setting used to cushion the landing, the more the throttle reduction will be. A coordinated throttle reduction and increased collective will result in a very smooth touchdown with some forward groundspeed. If the nose of the helicopter is to the left of the landing heading, a slight increase in collective or aft cyclic may be used to align the nose for touchdown. The decision to land or go around has to be made prior to any throttle reduction. Using airspeeds slightly above translational lift may be helpful to

ensure that the nose does not continue yawing to the right. If a go-around is required, increasing the collective too much or too rapidly with airspeeds below translational lift may cause a rapid spinning to the right.

Once the helicopter has landed and is sliding/rolling to a stop, the heading can be controlled with a combination of collective, cyclic and throttle. To turn the nose to the right, raise the collective or apply aft cyclic. The throttle may be increased as well if it is not in the full open position. To turn the nose to the left, lower the collective or apply forward cyclic. The throttle may be decreased as well if it is not already at flight idle.

Loss of Tail Rotor Effectiveness (LTE)

Loss of tail rotor effectiveness (LTE) or an unanticipated yaw is defined as an uncommanded, rapid yaw towards the advancing blade which does not subside of its own accord. It can result in the loss of the aircraft if left unchecked. It is very important for pilots to understand that LTE is caused by an aerodynamic interaction between the main rotor and tail rotor and not caused from a mechanical failure. Some helicopter types are more likely to encounter LTE due to the normal certification thrust produced by having a tail rotor that, although meeting certification standards, is not always able to produce the additional thrust demanded by the pilot.

A helicopter is a collection of compromises. Compare the size of an airplane propeller to that of a tail rotor. Then, consider the horsepower required to run the propeller. For example, a Cessna 172P is equipped with a 160-horsepower (HP) engine. A Robinson R-44 with a comparably sized tail rotor is rated for a maximum of 245 HP. If you assume the tail rotor consumes 50 HP, only 195 HP remains to drive the main rotor. If the pilot were to apply enough collective to require 215 HP from the engine, and enough left pedal to require 50 HP for the tail rotor, the resulting engine overload would lead to one of two outcomes: slow down (reduction in rpm) or premature failure. In either outcome, antitorque would be insufficient and total lift might be less than needed to remain airborne.

Every helicopter design requires some type of antitorque system to counteract main rotor torque and prevent spinning once the helicopter lifts off the ground. A helicopter is heavy, and the powerplant places a high demand on fuel. Weight penalizes performance, but all helicopters must have an antitorque system, which adds weight. Therefore, the tail rotor is certified for normal flight conditions. Environmental forces can overwhelm any aircraft, rendering the inherently unstable helicopter especially vulnerable.

As with any aerodynamic condition, it is very important for

pilots to not only to understand the definition of LTE, but more importantly, how and why it happens, how to avoid it, and lastly, how to correct it once it is encountered. We must first understand the capabilities of the aircraft or even better what it is not capable of doing. For example, if you were flying a helicopter with a maximum gross weight of 5,200 lb, would you knowingly try to take on fuel, baggage and passengers causing the weight to be 5,500 lb? A wise professional pilot should not ever exceed the certificated maximum gross weight or performance flight weight for any aircraft. The manuals are written for safety and reliability. The limitations and emergency procedures are stressed because lapses in procedures or exceeding limitations can result in aircraft damage or human fatalities. At the very least, exceeding limitations will increase the costs of maintenance and ownership of any aircraft and especially helicopters.

Overloaded parts may fail before their designed lifetime. There are no extra parts in helicopters. The respect and discipline pilots exercise in following flight manuals should also be applied to understanding aerodynamic conditions. If flight envelopes are exceeded, the end results can be catastrophic.

LTE is an aerodynamic condition and is the result of a control margin deficiency in the tail rotor. It can affect all single-rotor helicopters that utilize a tail rotor. The design of main and tail rotor blades and the tail boom assembly can affect the characteristics and susceptibility of LTE but will not nullify the phenomenon entirely. Translational lift is obtained by any amount of clean air through the main rotor disk. Chapter 2, Aerodynamics of Flight, discusses translational lift with respect to the main rotor blade, explaining that the more clean air there is going through the rotor disk, the more efficient it becomes. The same holds true for the tail rotor. As the tail rotor works in less turbulent air, it reaches a point of translational thrust. At this point, the tail rotor becomes aerodynamically efficient and the improved efficiency produces more antitorque thrust. The pilot can determine when the tail rotor has reached translational thrust. As more antitorque thrust is produced, the nose of the helicopter yaws to the left (opposite direction of the tail rotor thrust), forcing the pilot to correct with right pedal application (actually decreasing the left pedal). This, in turn, decreases the AOA in the tail rotor blades. Pilots should be aware of the characteristics of the helicopter they fly and be particularly aware of the amount of tail rotor pedal typically required for different flight conditions.

LTE is a condition that occurs when the flow of air through a tail rotor is altered in some way, by altering the angle or speed at which the air passes through the rotating blades of the tail rotor disk. As discussed in the previous paragraph, an effective tail rotor relies on a stable and relatively undisturbed

airflow in order to provide a steady and constant antitorque reaction. The pitch and AOA of the individual blades will determine the thrust. A change to either of these alters the amount of thrust generated. A pilot's yaw pedal input causes a thrust reaction from the tail rotor. Altering the amount of thrust delivered for the same yaw input creates an imbalance. Taking this imbalance to the extreme will result in the loss of effective control in the yawing plane, and LTE will occur.

This alteration of tail rotor thrust can be affected by numerous external factors. The main factors contributing to LTE are:

1. Airflow and downdraft generated by the main rotor blades interfering with the airflow entering the tail rotor assembly.
2. Main blade vortices developed at the main blade tips entering the tail rotor disk.
3. Turbulence and other natural phenomena affecting the airflow surrounding the tail rotor.
4. A high-power setting, hence large main rotor blade downwash and hence more turbulence than when the helicopter is in a low power condition.
5. A slow forward airspeed, typically at speeds where translational lift and translational thrust are in the process of change and airflow around the tail rotor will vary in direction and speed.
6. The airflow relative to the helicopter;
 - a. Worst case—relative wind within $\pm 15^\circ$ of the 10 o'clock position, generating vortices that can blow directly into the tail rotor. This is dictated by the characteristics of the helicopters aerodynamics of tailboom position, tail rotor size and position relative to the main rotor and vertical stabilizer, size and shape. [Figure 11-9]
 - b. Weathercock stability—tailwinds from 120° to 240° [Figure 11-10], such as left crosswinds, causing high pilot workload.
 - c. Tail rotor vortex ring state (210° to 330°). [Figure 11-11] Winds within this region will result in the development of the vortex ring state of the tail rotor.
7. Combinations (a, b, c) of these factors in a particular situation can easily require more antitorque than the helicopter can generate and in a particular environment LTE can be the result.

Certain flight activities lend themselves to being at higher risk of LTE than others. For example, power line and pipeline patrol sectors, low speed aerial filming/photography as well as in the Police and Helicopter Emergency Medical Services

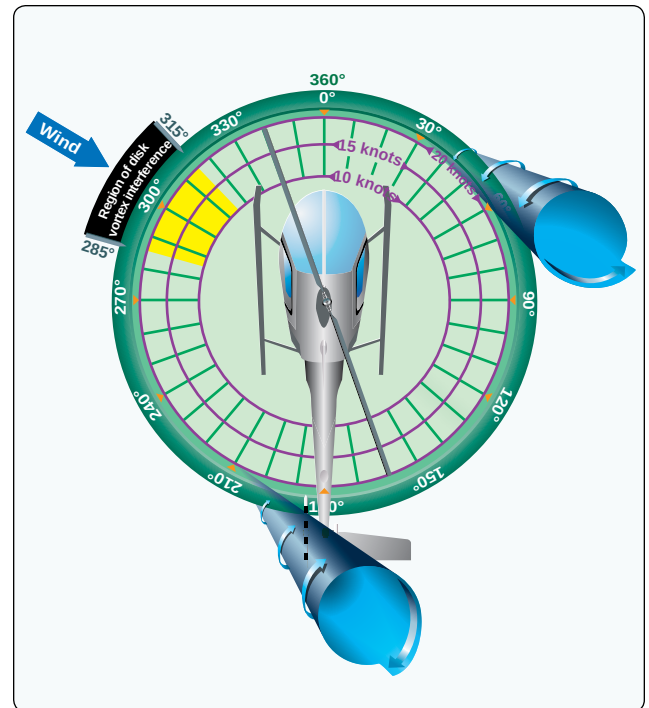


Figure 11-9. Main rotor disk vortex interference.

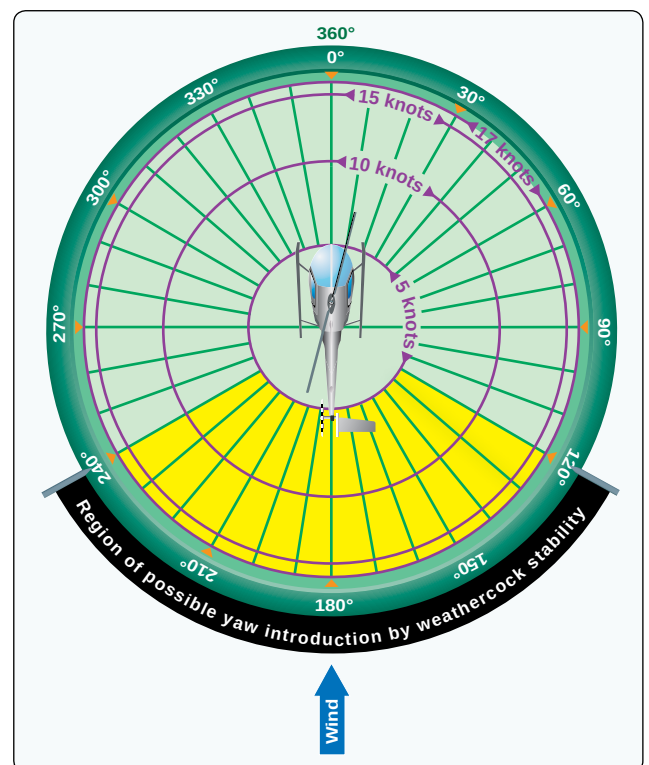


Figure 11-10. Weathercock stability.

(EMS) environments can find themselves in low-and-slow situations over geographical areas where the exact wind speed and direction are hard to determine.

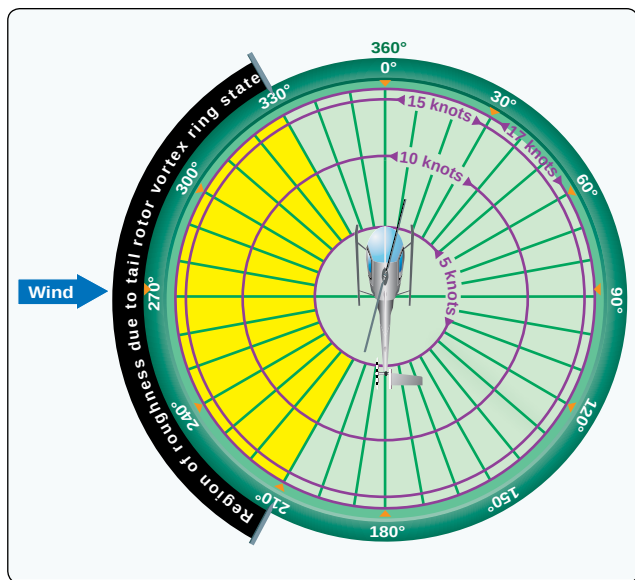


Figure 11-11. Tail rotor vortex ring state.

Unfortunately, the aerodynamic conditions that a helicopter is susceptible to are not explainable in black and white terms. LTE is no exception. There are a number of contributing factors, but what is more important in preventing LTE is to note them, and then to associate them with situations that should be avoided. Whenever possible, pilots should learn to avoid the following combinations:

1. Low and slow flight outside of ground effect.
2. Winds from $\pm 15^\circ$ of the 10 o'clock position and probably on around to 5 o'clock position [Figure 11-9]
3. Tailwinds that may alter the onset of translational lift and translational thrust, and hence induce high power demands and demand more anti-torque (left pedal) than the tail rotor can produce.
4. Low speed downwind turns.
5. Large changes of power at low airspeeds.
6. Low speed flight in the proximity of physical obstructions that may alter a smooth airflow to both the main rotor and tail rotor.

Pilots who put themselves in situations where the combinations above occur should know that they are likely to encounter LTE. The key is not to put the helicopter in a compromising condition, while at the same time being educated enough to recognize the onset of LTE and being prepared to react quickly to it before the helicopter cannot be controlled.

Early detection of LTE, followed by the immediate flight control application of corrective action, applying forward cyclic to regain airspeed, applying right pedal not left as

necessary to maintain rotor rpm, and reducing the collective (thus reducing the high-power demand on the tail rotor), is the key to a safe recovery. Pilots should always set themselves up when conducting any maneuver to have enough height and space available to recover in the event they encounter an aerodynamic situation such as LTE.

Understanding the aerodynamic phenomenon of LTE is by far the most important factor in preventing an LTE-related accident, and maintaining the ability and option either to go around if making an approach or pull out of a maneuver safely and re-plan, is always the safest option. Having the ability to fly away from a situation and re-think the possible options should always be part of a pilot's planning process in all phases of flight. Unfortunately, there have been many pilots who have idled a good engine and fully functioning tail rotor disk and autorotated a perfectly airworthy helicopter to the crash site because they misunderstood or misperceived both the limitations of the helicopter and the aerodynamic situation.

Main Rotor Disk Interference (285–315°)

Refer to Figure 11-9. Winds at velocities of 10–30 knots from the left front cause the main rotor vortex to be blown into the tail rotor by the relative wind. This main rotor disk vortex causes the tail rotor to operate in an extremely turbulent environment. During a right turn, the tail rotor experiences a reduction of thrust as it comes into the area of the main rotor disk vortex. The reduction in tail rotor thrust comes from the airflow changes experienced at the tail rotor as the main rotor disk vortex moves across the tail rotor disk.

The effect of the main rotor disk vortex initially increases the AOA of the tail rotor blades, thus increasing tail rotor thrust. The increase in the AOA requires that right pedal pressure be added to reduce tail rotor thrust in order to maintain the same rate of turn. As the main rotor vortex passes the tail rotor, the tail rotor AOA is reduced. The reduction in the AOA causes a reduction in thrust and right yaw acceleration begins. This acceleration can be surprising, since previously adding right pedal to maintain the right turn rate. This thrust reduction occurs suddenly, and if uncorrected, develops into an uncontrollable rapid rotation about the mast. When operating within this region, be aware that the reduction in tail rotor thrust can happen quite suddenly, and be prepared to react quickly to counter this reduction with additional left pedal input.

Weathercock Stability (120–240°)

In this region, the helicopter attempts to weathervane, or weathercock, its nose into the relative wind. [Figure 11-10] Unless a resisting pedal input is made, the helicopter starts a slow, uncommanded turn either to the right

or left, depending upon the wind direction. If the pilot allows a right yaw rate to develop and the tail of the helicopter moves into this region, the yaw rate can accelerate rapidly. In order to avoid the onset of LTE in this downwind condition, it is imperative to maintain positive control of the yaw rate and devote full attention to flying the helicopter.

Tail Rotor Vortex Ring State (210–330°)

Winds within this region cause a tail rotor vortex ring state to develop. [Figure 11-11] The result is a nonuniform, unsteady flow into the tail rotor. The vortex ring state causes tail rotor thrust variations, which result in yaw deviations. The net effect of the unsteady flow is an oscillation of tail rotor thrust. Rapid and continuous pedal movements are necessary to compensate for the rapid changes in tail rotor thrust when hovering in a left crosswind. Maintaining a precise heading in this region is difficult, but this characteristic presents no significant problem unless corrective action is delayed. However, high pedal workload, lack of concentration, and overcontrolling can lead to LTE.

When the tail rotor thrust being generated is less than the thrust required, the helicopter yaws to the right. When hovering in left crosswinds, concentrate on smooth pedal coordination and do not allow an uncommanded right yaw to develop. If a right yaw rate is allowed to build, the helicopter can rotate into the wind azimuth region where weathercock stability then accelerates the right turn rate. Pilot workload during a tail rotor vortex ring state is high. Do not allow a right yaw rate to increase.

LTE at Altitude

At higher altitudes where the air is thinner, tail rotor thrust and efficiency are reduced. Because of the high-density altitude, powerplants may be much slower to respond to power changes. When operating at high altitudes and high gross weights, especially while hovering, the tail rotor thrust may not be sufficient to maintain directional control, and LTE can occur. In this case, the hovering ceiling is limited by tail rotor thrust and not necessarily power available. In these conditions, gross weights need to be reduced and/or operations need to be limited to lower density altitudes. This may not be noted as criteria on the performance charts.

Reducing the Onset of LTE

To help reduce the onset of LTE, follow these steps:

1. Maintain maximum power-on rotor rpm. If the main rotor rpm is allowed to decrease, the antitorque thrust available is decreased proportionally.
2. Avoid tailwinds below airspeeds of 30 knots. If loss of translational lift occurs, it results in an increased

power demand and additional antitorque pressures.

3. Avoid OGE operations and high-power demand situations below airspeeds of 30 knots at low altitudes.
4. Be especially aware of wind direction and velocity when hovering in winds of about 8–12 knots. A loss of translational lift results in an unexpected high power demand and an increased antitorque requirement.
5. Be aware that if a considerable amount of left pedal is being maintained, a sufficient amount of left pedal may not be available to counteract an unanticipated right yaw.
6. Be alert to changing wind conditions, which may be experienced when flying along ridge lines and around buildings.
7. Execute right turns slowly. This limits the effects of rotating inertia, and decreases loading on the tailrotor to control yawing.

Recovery Technique (Uncontrolled Right Yaw)

If a sudden unanticipated right yaw occurs, the following recovery technique should be performed. Apply full left pedal. Simultaneously, apply forward cyclic control to increase speed. If altitude permits, reduce power. As recovery is affected, adjust controls for normal forward flight. A recovery path must always be planned, especially when terminating to an OGE hover and executed immediately if an uncommanded yaw is evident.

Collective pitch reduction aids in arresting the yaw rate but may cause an excessive rate of descent. Any large, rapid increase in collective to prevent ground or obstacle contact may further increase the yaw rate and decrease rotor rpm. The decision to reduce collective must be based on the pilot's assessment of the altitude available for recovery.

If the rotation cannot be stopped and ground contact is imminent, an autorotation may be the best course of action. Maintain full left pedal until the rotation stops, then adjust to maintain heading. For more information on LTE, see Advisory Circular (AC) 90-95, Unanticipated Right Yaw in Helicopters.

Main Drive Shaft or Clutch Failure

The main drive shaft, located between the engine and the main rotor transmission, provides engine power to the main rotor transmission. In some helicopters, particularly those with piston engines, a drive belt is used instead of a drive shaft. A failure of the drive shaft clutch or belt has the same effect as an engine failure because power is no longer provided to the main rotor and an autorotation must be initiated. There are a few differences, however, that need to be taken into

consideration. If the drive shaft or belt breaks, the lack of any load on the engine results in an overspeed. In this case, the throttle must be closed in order to prevent any further damage. In some helicopters, the tail rotor drive system continues to be powered by the engine even if the main drive shaft breaks. In this case, when the engine unloads, a tail rotor overspeed can result. If this happens, close the throttle immediately and enter an autorotation. The pilot must be knowledgeable of the specific helicopter's system and failure modes.

Pilots should keep in mind that when there is any suspected mechanical malfunction, first and foremost they should always attempt to maintain rotor rpm. If the rotor rpm is at the normal indication with normal power settings, an instrument failure might be occurring, and it would be best to fly the helicopter to a safe landing area. If the rotor rpm is in fact decreasing or low, then there is a drive line failure.

Hydraulic Failure

Many helicopters incorporate the use of hydraulic actuators to overcome high control forces. A hydraulic system consists of actuators, also called servos, on each flight control; a pump, which is usually driven by the main rotor transmission; and a reservoir to store the hydraulic fluid. A switch in the cockpit can turn the system off, although it is left on during normal conditions. A pressure indicator in the cockpit may be installed to monitor the system.

An impending hydraulic failure can be recognized by a grinding or howling noise from the pump or actuators, increased control forces and feedback, and limited control movement. The required corrective action is stated in detail in the RFM. In most cases, airspeed needs to be reduced in order to reduce control forces. The hydraulic switch and circuit breaker should be checked and recycled. If hydraulic power is not restored, make a shallow approach to a running or roll-on landing. This technique is used because it requires less control force and pilot workload. Additionally, the hydraulic system should be disabled by placing the switch in the off position. The reason for this is to prevent an inadvertent restoration of hydraulic power, which may lead to overcontrolling near the ground.

In those helicopters in which the control forces are so high that they cannot be moved without hydraulic assistance, two or more independent hydraulic systems are installed. Some helicopters use hydraulic accumulators to store pressure that can be used for a short time while in an emergency if the hydraulic pump fails. This gives enough time to land the helicopter with normal control.

Governor or Fuel Control Failure

Governors and fuel control units automatically adjust engine power to maintain rotor rpm when the collective pitch is changed. If the governor or fuel control unit fails, any change in collective pitch requires manual adjustment of the throttle to maintain correct rpm. In the event of a high side failure, the engine and rotor rpm tend to increase above the normal range due to the engine being commanded to put out too much power. If the rpm cannot be reduced and controlled with the throttle, close the throttle and enter an autorotation. If the failure is on the low side, the engine output is allowed to go below the collective and normal rpm may not be attainable, even if the throttle is manually controlled. In this case, the collective has to be lowered to maintain rotor rpm. A running or roll-on landing may be performed if the engine can maintain sufficient rotor rpm. If there is insufficient power, enter an autorotation. As stated previously in this chapter, before responding to any type of mechanical failure, pilots should confirm that rotor rpm is not responding to flight control inputs. If the rotor rpm can be maintained in the green operating range, the failure is in the instrument, and not mechanical.

Abnormal Vibration

With the many rotating parts found in helicopters, some vibration is inherent. A pilot needs to understand the cause and effect of helicopter vibrations because abnormal vibrations cause premature component wear and may even result in structural failure. With experience, a pilot learns what vibrations are normal and those that are abnormal and can then decide whether continued flight is safe or not. Helicopter vibrations are categorized into low, medium, or high frequency.

Low-Frequency Vibrations

Low-frequency vibrations (100–500 cycles per minute) usually originate from the main rotor disk. The main rotor operational range, depending on the helicopter, is usually between 320 and 500 rpm. A rotor blade that is out of track or balance will cause a cycle to occur with every rotation. The vibration may be felt through the controls, the airframe, or a combination of both. The vibration may also have a definite direction of push or thrust. It may be vertical, lateral, horizontal, or even a combination of these. Normally, the direction of the vibration can be determined by concentrating on the feel of the vibration, which may push a pilot up and down, backwards and forwards, or in the case of a blade being out of phase, from side to side. The direction of the vibration and whether it is felt in the controls or the airframe is important information for the mechanic when he or she troubleshoots the source. Out-of-track or out-of-balance main rotor blades, damaged blades,

worn bearings, dampers out of adjustment, or worn parts are possible causes of low frequency vibrations.

Medium- and High-Frequency Vibrations

Medium-frequency vibrations (1,000–2,000 cycles per minute) range between the low frequencies of the main rotor (100–500 cycles per minute) and the high frequencies (2,100 cycles per minute or higher) of the engine and tail rotor. Depending on the helicopter, medium-frequency vibration sources may be engine and transmission cooling fans, and accessories such as air conditioner compressors, or driveline components. Medium-frequency vibrations are felt through the entire airframe, and prolonged exposure to the vibrations will result in greater pilot fatigue.

Most tail rotor vibrations fall into the high-frequency range (2,100 cycles per minute or higher) and can be felt through the tail rotor pedals as long as there are no hydraulic actuators to dampen out the vibration. This vibration is felt by the pilot through his or her feet, which are usually “put to sleep” by the vibration. The tail rotor operates at approximately a 6:1 ratio with the main rotor, meaning for every one rotation of the main rotor the tail rotor rotates 6 times. A main rotor operating rpm of 350 means the tail rotor rpm would be 2,100 rpm. Any imbalance in the tail rotor disk is very harmful as it can cause cracks to develop and rivets to work loose. Piston engines usually produce a normal amount of high-frequency vibration, which is aggravated by engine malfunctions, such as spark plug fouling, incorrect magneto timing, carburetor icing and/or incorrect fuel/air mixture. Vibrations in turbine engines are often difficult to detect as these engines operate at a very high rpm. Turbine engine vibration can be at 30,000 rpm internally, but common transmission speeds are in the 1,000 to 3,000 rpm range for the output shaft. The vibrations in turbine engines may be short lived as the engine disintegrates rapidly when damaged due to high rpm and the forces present.

Tracking and Balance

Modern equipment used for tracking and balancing the main and tail rotor blades can also be used to detect other vibrations in the helicopter. These systems use accelerometers mounted around the helicopter to detect the direction, frequency, and intensity of the vibration. The built-in software can then analyze the information, pinpoint the origin of the vibration, and suggest the corrective action.

The use of a system such as a health and usage monitoring system (HUMS) provides the operator the ability to record engine and transmission performance and provide rotor track and balance. This system has been around for over 30 years and is now becoming more affordable, more capable, and more commonplace in the rotorcraft industry.

Multiengine Emergency Operations

Single-Engine Failure

When one engine has failed, the helicopter can often maintain altitude and airspeed until a suitable landing site can be selected. Whether or not this is possible becomes a function of such combined variables as aircraft weight, density altitude, height above ground, airspeed, phase of flight, and single-engine capability. Environmental response time and control technique may be additional factors. Caution must be exercised to correctly identify the malfunctioning engine since there is no telltale yawing as occurs in most multiengine airplanes. Shutting down the wrong engine could be disastrous!

Even when flying multiengine powered helicopters, rotor rpm must be maintained at all costs, because fuel contamination has been documented as the cause for both engines failing in flight.

Dual-Engine Failure

The flight characteristics and the required crew member control responses after a dual-engine failure are similar to those during a normal power-on descent. Full control of the helicopter can be maintained during autorotational descent. In autorotation, as airspeed increases above 70–80 KIAS, the rate of descent and glide distance increase significantly. As airspeed decreases below approximately 60 KIAS, the rate of descent increases and glide distance decreases.

Lost Procedures

Pilots become lost while flying for a variety of reasons, such as disorientation, flying over unfamiliar territory, or visibility that is low enough to render familiar terrain unfamiliar. When a pilot becomes lost, the first order of business is to fly the aircraft; the second is to implement lost procedures. Keep in mind that the pilot workload will be high, and increased concentration will be necessary. If lost, always remember to look for the practically invisible hazards, such as wires, by searching for their support structures, such as poles or towers, which are almost always near roads.

If lost, follow common sense procedures.

- Try to locate any large landmarks, such as lakes, rivers, towers, railroad tracks, or Interstate highways. If a landmark is recognized, use it to find the helicopter's location on the sectional chart. If flying near a town or city, a pilot may be able to read the name of the town on a water tower or even land to ask for directions.
- If no town or city is nearby, the first thing a pilot should do is climb. An increase in altitude increases radio and navigation reception range as well as radar coverage.

- Navigation aids, dead reckoning, and pilotage are skills that can be used as well.
- Do not forget air traffic control (ATC)—controllers assist pilots in many ways, including finding a lost helicopter. Once communication with ATC has been established, follow their instructions.

These common-sense procedures can be easily remembered by using the four Cs: Climb, Communicate, Confess, and Comply.

- Climb for a better view, improved communication and navigation reception, and terrain avoidance.
- Communicate by calling the nearest flight service station (FSS)/automated flight service station (AFSS) on 122.2 MHz. If the FSS/AFSS does not respond, call the nearest control tower, center, or approach control. For frequencies, check the chart in the vicinity of the last known position. If that fails, switch to the emergency radio frequency (121.5 MHz) and transponder code (7700).
- Report the lost situation to ATC and request help.
- Comply with controller instructions.

Pilots should understand the services provided by ATC and the resources and options available. These services enable pilots to focus on aircraft control and help them make better decisions in a time of stress.

When contacting ATC, pilots should provide as much information as possible because ATC uses the information to determine what kind of assistance it can provide with available assets and capabilities. Information requirements vary depending on the existing situation, but at a minimum a pilot should provide the following information:

- Aircraft identification and type
- Nature of the emergency
- Aviator's desires

To reduce the chances of getting lost in the first place, use flight following through active contact with an aircraft during flight either by radio or through automated flight following systems when it is available, monitor checkpoints no more than 25 miles apart, keep navigation aids such as Very High-Frequency Omni-Directional Range (VOR) tuned in, and maintain good situational awareness. Flight following provides ongoing surveillance information to assist pilots in avoiding collisions with other aircraft.

Getting lost is a potentially dangerous situation for any aircraft, especially when low on fuel. Due to the helicopter's unique ability to land almost anywhere, pilots have more flexibility than other aircraft as to landing site. An inherent

risk associated with being lost is waiting too long to land in a safe area. Helicopter pilots should land before fuel exhaustion occurs because maneuvering with low fuel levels could cause the engine to stop due to fuel starvation as fuel sloshes or flows away from the pickup port in the tank.

If lost and low on fuel, it is advisable to make a precautionary landing. Preferably, land near a road or in an area that would allow space for another helicopter to safely land and provide assistance. Having fuel delivered is a minor inconvenience when compared to having an accident. Once on the ground, pilots may seek assistance.

VFR Flight into Instrument Meteorological Conditions

Helicopters, unlike airplanes, generally operate under Visual Flight Rules (VFR) and require pilots to maintain aircraft control by visual cues. However, when unforecast weather leads to degraded visibility, the pilot may be at increased risk of Inadvertent flight into Instrument Meteorological Conditions (IIMC). During an IIMC encounter, the pilot may be unprepared for the loss of visual reference, resulting in a reduced ability to continue safe flight. IIMC is a life-threatening emergency for any pilot. To capture these IIMC events, the Commercial Aviation Safety Team (CAST) and International Civil Aviation Organization (ICAO) Common Taxonomy Team (CICCTT) categorizes this occurrence as Unintended flight in Instrument Meteorological Conditions (UIMC). This term is also recognized by the National Transportation Safety Board (NTSB) and Federal Aviation Administration (FAA). It is used to classify occurrences (accidents and incidents) at a high level to improve the capacity to focus on common safety issues and complete analysis of the data in support of safety initiatives.

The onset of IIMC may occur gradually or suddenly, has no simple procedural exit, and is unlike flight training by reference to while in Visual Meteorological Conditions (VMC). Most training helicopters are not equipped or certified to fly under Instrument Flight Rules (IFR). Therefore, General Aviation (GA) helicopter pilots may not have the benefit of flight in actual Instrument Meteorological Conditions (IMC) during their flight training. Helicopter pilots that encounter IIMC may experience physiological illusions which can lead to spatial disorientation and loss of aircraft control. Even with some instrument training, many available and accessible helicopters are not equipped with the proper augmented safety systems or autopilots, which would significantly aid in helicopter control during an IIMC emergency. The need to use outside visual references is natural for helicopter pilots because much of their flight training is based upon visual cues, not on flight instruments. This primacy can only be overcome through significant instrument training. Additionally, instrument flight may be

intimidating to some and too costly for others. As a result, many helicopter pilots choose not to seek an instrument rating.

While commercial helicopter operators often prefer their pilots to be instrument rated, fatal accidents still occur as a result of IIMC. Many accidents can be traced back to the pilot's inability to recover the helicopter after IIMC is encountered, even with adequate equipment installed. Therefore, whether instrument rated or not, all pilots should understand that avoiding IIMC is critical.

A good practice for any flight is to set and use personal minimums, which should be more conservative than those required by regulations for VFR flight. In addition, a thorough preflight and understanding of weather conditions that may contribute to the risk of IMC developing along a planned route of flight is essential for safety. Pilots should recognize deteriorating weather conditions so the route of flight can be changed or a decision made to terminate the flight and safely land at a suitable area, well before IIMC occurs. If weather conditions deteriorate below the pilot's personal minimums during flight, a pilot who understands the risks of IIMC knows that he or she is at an en route decision point, where it is necessary to either turn back to the departure point or immediately land somewhere safe to wait until the weather has cleared. Pilots should recognize that descent below a predetermined minimum altitude above ground level (AGL) (for example, 500 feet AGL) to avoid clouds or, slowing the helicopter to a predetermined minimum airspeed (for example, slowing to 50 KIAS) to reduce the rate of closure from the deteriorating weather conditions, indicates the decision point had been reached. Ceilings that are lower than reported and/or deteriorating visibility along the route of flight should trigger the decision to discontinue and amend the current route to avoid IIMC.

If the helicopter pilot is instrument rated, it is advisable to maintain instrument currency and proficiency as this may aid the pilot in a safe recovery from IIMC. A consideration for instrument rated pilots when planning a VFR flight should include a review of published instrument charts for safe operating altitudes, e.g. minimum safe altitude (MSA), minimum obstruction clearance altitude (MOCA), minimum in VMC throughout a flight: off-route altitude (MORA), etc. If IIMC occurs, the pilot may consider a climb to a safe altitude. Once the helicopter is stabilized, the pilot should declare an emergency with air traffic control (ATC). It is imperative that the pilot commit to controlling the helicopter and remember to aviate, navigate, and finally communicate. Often communication is attempted first, as it is natural to look for help in stressful situations. This may distract the pilot from maintaining control of the helicopter.

If the pilot is not instrument rated, instrument current nor proficient, or is flying a non-IFR equipped helicopter, remaining in VMC is paramount. Pilots who are not trained or proficient in flight solely by reference to instruments have a tendency to attempt to maintain flight by visual ground reference, which tends to result in flying at lower altitudes, just above the trees or by following roads. The thought process is that, "as long as I can see what is below me, I can continue to my intended destination." Experience and statistical data indicate that attempting to continue VFR flight into IMC can often lead to a fatal outcome as pilots often fixate on what they see below them and are unable to see the hazards ahead of them (e.g., power lines, towers, rising terrain, etc.). By the time the pilot sees the hazard, it is either too late to avoid a collision, or while successfully maneuvering to avoid an obstacle, the pilot becomes disoriented.

Flying at night involves even more conservative personal minimums to ensure safety and avoidance of IIMC than daytime flying. At night, deteriorating weather conditions may be difficult to detect. Therefore, pilots should ensure that they not only receive a thorough weather briefing, but that they remain vigilant for unforecasted weather during their flight. The planned route should include preselected landing sites that will provide options to the pilot in the event a precautionary landing is required to avoid adverse weather conditions. As a pilot gains night flight experience their ability to assess weather during a flight will improve.

Below are some basic guidelines to assist a pilot to remain in VMC throughout a flight:

1. Slowly turn around if threatened by deteriorating visual cues and proceed back to VMC or to the first safe landing area if the weather ahead becomes questionable. Remember that prevention is paramount.
2. Do not proceed further on a course when the terrain ahead is not clearly discernible.
3. Delay or consider cancelling the flight if weather conditions are already questionable, could deteriorate significantly based on forecasts, or if you are uncertain whether the flight can be conducted safely. Often, a gut feeling can provide a warning that unreasonable risks are present.
4. Always have a safe landing area (such as large open areas or airports) in mind for every route of flight.

There are five basic steps that every pilot should be familiar with, and which should be executed immediately at the onset of IIMC, if applicable. However, remember that if you are not trained to execute the following maneuvers solely by reference to instruments, or your aircraft is not equipped

with such instruments, this guidance may be less beneficial to you and loss of helicopter control may occur:

1. Level the “wings” – level the bank angle using the attitude indicator.
2. Attitude – set a climb attitude that achieves a safe climb speed appropriate to your type of helicopter. This is often no more than 10° of pitch up on the attitude indicator.
3. Airspeed – verify that the attitude selected has achieved the desired airspeed. It is critical to recognize that slower airspeeds, closer to effective translational lift, may require large control inputs and will decrease stability, making recover impossible while in UIMC.
4. Power – adjust to a climb power setting relative to the desired airspeed. This should be executed concurrent with steps 2 and 3.
5. Heading and Trim – pick a heading known to be free of obstacles and maintain it. This will likely be the heading you were already on, which was planned and briefed. Set the heading bug, if installed, to avoid over-controlling your bank. Maintain coordinated flight so that an unusual attitude will not develop.

Try to avoid immediately turning 180°. Turning around is not always the safest route and executing a turn immediately after UIMC may lead to spatial disorientation. If a 180° turn is the safest option, first note the heading you are on then begin the turn to the reciprocal heading, but only after stable flight is achieved (items 1 through 5 above) and maintain a constant rate of turn appropriate to the selected airspeed.

Each encounter with UIMC is unique, and no single procedure can ensure a safe outcome. Considerations in determining the best course of action upon encountering UIMC should include, at a minimum, terrain, obstructions, freezing levels, aircraft performance and limitations, and availability of ATC services.

There are new technologies being developed regarding aircraft design, enhanced and lower-cost technologies, and aircraft certification. Because of this promising future, much of the discussion and guidance in this chapter may one day become irrelevant. As helicopters integrate more into the National Airspace System, the IFR infrastructure and instrument training will become more prevalent. In the future, UIMC may no longer be the emergency that ends with a fatality but rather associated with proper prevention, skilled recovery techniques along with the aid of emerging new life saving avionics technology. A helicopter instrument rating may be a life-saving addition to a pilot’s level of

EMERGENCY EQUIPMENT AND SURVIVAL GEAR	
Food cannot be subject to deterioration due to heat or cold. There should be at least 10,000 calories for each person on board, and it should be stored in a sealed waterproof container. It should have been inspected within the previous 6 months, verifying the amount and satisfactory condition of the contents.	
A supply of water	
Cooking utensils	
Matches in a waterproof container	
A portable compass	
An ax weighing at least 2.5 pounds with a handle not less than 28 inches in length	
A flexible saw blade or equivalent cutting tool	
30 feet of snare wire and instructions for use	
Fishing equipment, including still-fishing bait and gill net with not more than a two-inch mesh	
Mosquito nets or netting and insect repellent sufficient to meet the needs of all persons aboard, when operating in areas where insects are likely to be hazardous	
A signaling mirror	
At least three pyrotechnic distress signals	
A sharp, quality jackknife or hunting knife	
A suitable survival instruction manual	
Flashlight with spare bulbs and batteries	
Portable emergency locator transmitter (ELT) with spare batteries	
Stove with fuel or a self-contained means of providing heat for cooking	
Tent(s) to accommodate everyone on board	
Additional items for winter operations: • Winter sleeping bags for all persons when the temperature is expected to be below 7 °C • Two pairs of snow shoes • Spare ax handle • Ice chisel • Snow knife or saw knife	

Figure 11-12. *Emergency equipment and survival gear.*

certification. Please refer to the Instrument Flying Handbook (FAA-H-8083-15, as revised); Advanced Avionics Handbook (FAA-H-8083-6, as revised); and the Pilot’s Handbook of Aeronautical Knowledge (FAA-H-8083-25, as revised) for further exploration of IFR operations and how to obtain an instrument rating.

When faced with deteriorating weather, planning and prevention, not recovery, are the best strategies to eliminate UIMC-related accidents and fatalities.

Emergency Equipment and Survival Gear

Both Canada and Alaska require pilots to carry survival gear. Always carry survival gear when flying over rugged and desolate terrain. The items suggested in *Figure 11-12* are both weather and terrain dependent. The pilot also needs to consider how much storage space the helicopter has and how the equipment being carried affects the overall weight and balance of the helicopter.

Chapter Summary

Emergencies should always be anticipated. Knowledge of the helicopter, possible malfunctions and failures, and methods of recovery can help the pilot avoid accidents and be a safer pilot. Helicopter pilots should always expect the worse hazards and possible aerodynamic effects and plan for a safe exit path or procedure to compensate for the hazard.

Chapter 12

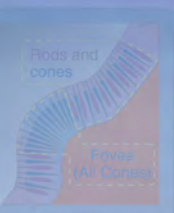
Night Operations

Introduction

Pilots rely more on vision than on any other sense to orient themselves in flight. The following visual factors contribute to flying performance: good depth perception for safe landings, good visual acuity to identify terrain features and obstacles in the flightpath, and good color vision. Although vision is the most accurate and reliable sense, visual cues can be misleading, contributing to incidents occurring within the flight environment. Pilots should be aware of and know how to compensate effectively for the following:

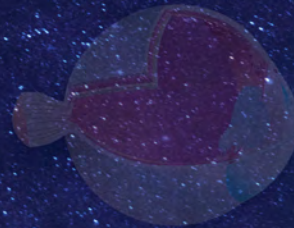
- Physical deficiency or self-imposed stress, such as smoking, which limits night-vision capability
- Visual cue deficiencies
- Limitations in visual acuity, dark adaptation, and color and depth perception

For example, at night, the unaided eye has degraded visual acuity. For more information on night operations, reference Chapter 17, Aeromedical Factors, of the Pilot's Handbook of Aeronautical Knowledge (FAA-H-8083-25, as revised).

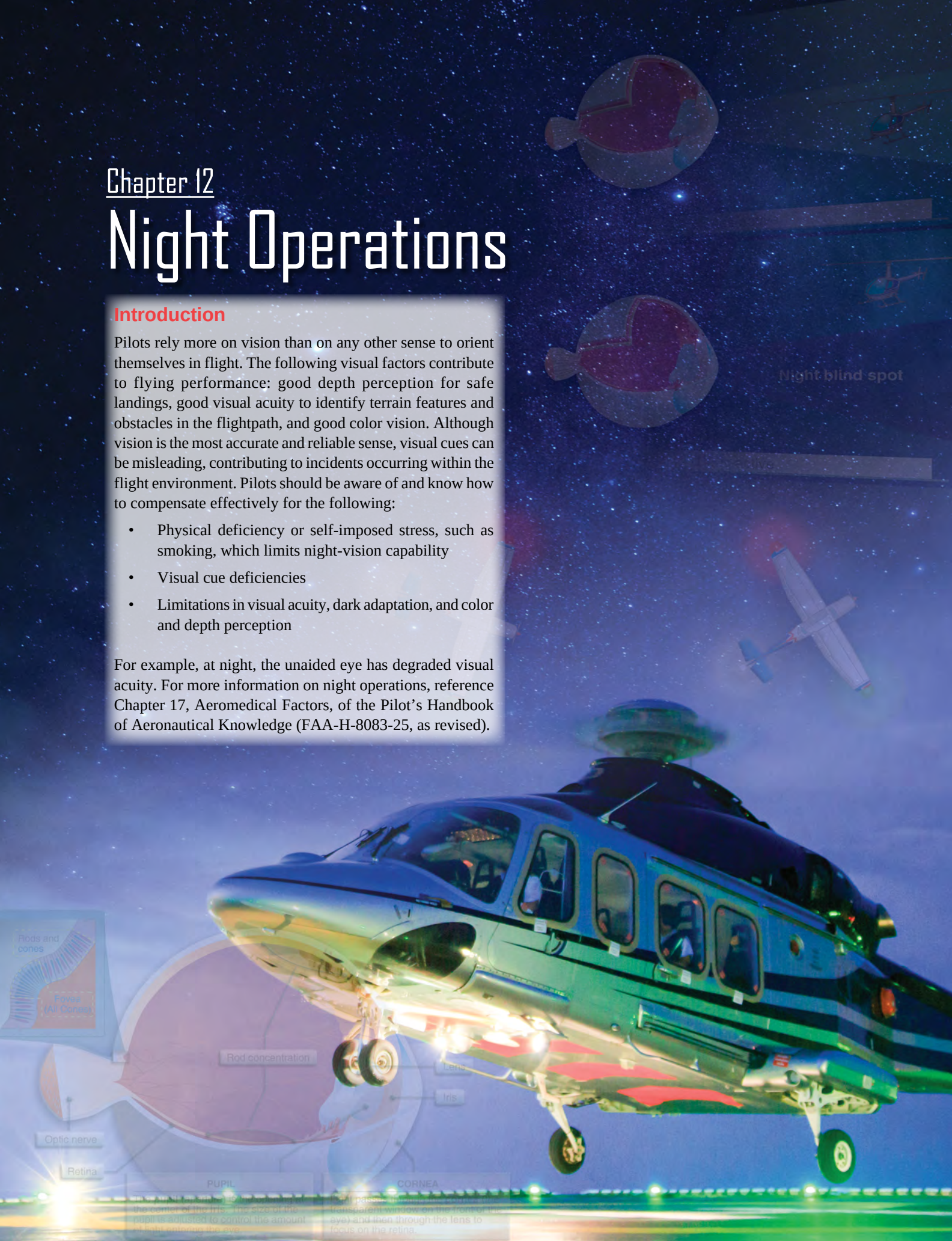


The pupil is the opening in the center of the iris. The size of the pupil is adjusted to control the amount of light entering the eye.

The cornea is the transparent window on the front of the eye and then through the lens to focus on the retina.



Night blind spot



Visual Deficiencies

Night Myopia

At night, blue wavelengths of light prevail in the visible portion of the spectrum. Therefore, slightly nearsighted (myopic) individuals viewing blue-green light at night may experience blurred vision. Even pilots with perfect vision find that image sharpness decreases as pupil diameter increases. For individuals with mild refractive errors, these factors combine to make vision unacceptably blurred unless they wear corrective glasses. Another factor to consider is “dark focus.” When light levels decrease, the focusing mechanism of the eye may move toward a resting position and make the eye more myopic. These factors become important when pilots rely on terrain features during unaided night flights. Practicing good light discipline is very important and helps pilots to retain their night adaptation. Keeping the cockpit lighting on dim allows the pilot to better identify outside details, unmarked hazards such as towers less than 200' AGL, and unimproved landing sites with no hazard lighting.

A simple exercise that shows the effect of high versus low light contrast would be to go out to a very dark road and turn the dash board lights down very low or off and let your eyes adjust to the ambient light level. Then, turn the dash board lights up and note how the outside features disappear. The same concept applies to cockpit lighting and being able to see the surrounding terrain and obstacles. [Figure 12-1] Special corrective lenses can be prescribed to pilots who experience night myopia.

The eye automatically adjusts for the light level experienced. During night flight, the cockpit and instrument lights should



Figure 12-1. Effects of dimming cockpit lighting during night flight to better see surrounding terrain.

be as dim as possible. The eye can then adjust for the outside lighting conditions (ambient lighting) to see outside. The dimmer the inside lighting is, the better you can see outside.

Hyperopia

Hyperopia is also caused by an error in refraction. In a hyperopic state, when a pilot views a near image, the actual focal point of the eye is behind the retinal plane (wall), causing blurred vision. Objects that are nearby are not seen clearly; only more distant objects are in focus. This problem, is referred to as farsightedness.

Astigmatism

An unequal curvature of the cornea or lens of the eye causes this condition. A ray of light is spread over a diffused area in one meridian. In normal vision, a ray of light is sharply focused on the retina. Astigmatism is the inability to focus different meridians simultaneously. If, for example, astigmatic individuals focus on power poles (vertical), the wires (horizontal) are out of focus for most of them. [Figure 12-2]

Presbyopia

This condition is part of the normal aging process, which causes the lens to harden. Beginning in the early teens, the human eye gradually loses the ability to accommodate for and focus on nearby objects. When people are about 40 years old, their eyes are unable to focus at normal reading distances without reading glasses. Reduced illumination interferes with focus depth and accommodation ability. Hardening of the lens may also result in clouding of the lens (cataract formation). Aviators with early cataracts may see a standard eye chart clearly under normal daylight but have difficulty seeing under bright light conditions. This problem is due to light scattering as it enters the eye. This glare sensitivity is disabling under certain circumstances. Glare disability, related to contrast sensitivity, is the ability to detect objects against varying shades of backgrounds. Other visual functions decline with age and affect the aircrew member's performance:

- Dynamic acuity
- Recovery from glare
- Function under low illumination
- Information processing

Vision in Flight

The visual sense is especially important in collision avoidance and depth perception. Due to the structure of the human eye, illusions and blindspots occur. The more pilots understand the eye and how it functions, the easier it is to compensate for these illusions and blindspots. Figure 12-3 shows the basic anatomy of the human eye and how it is like

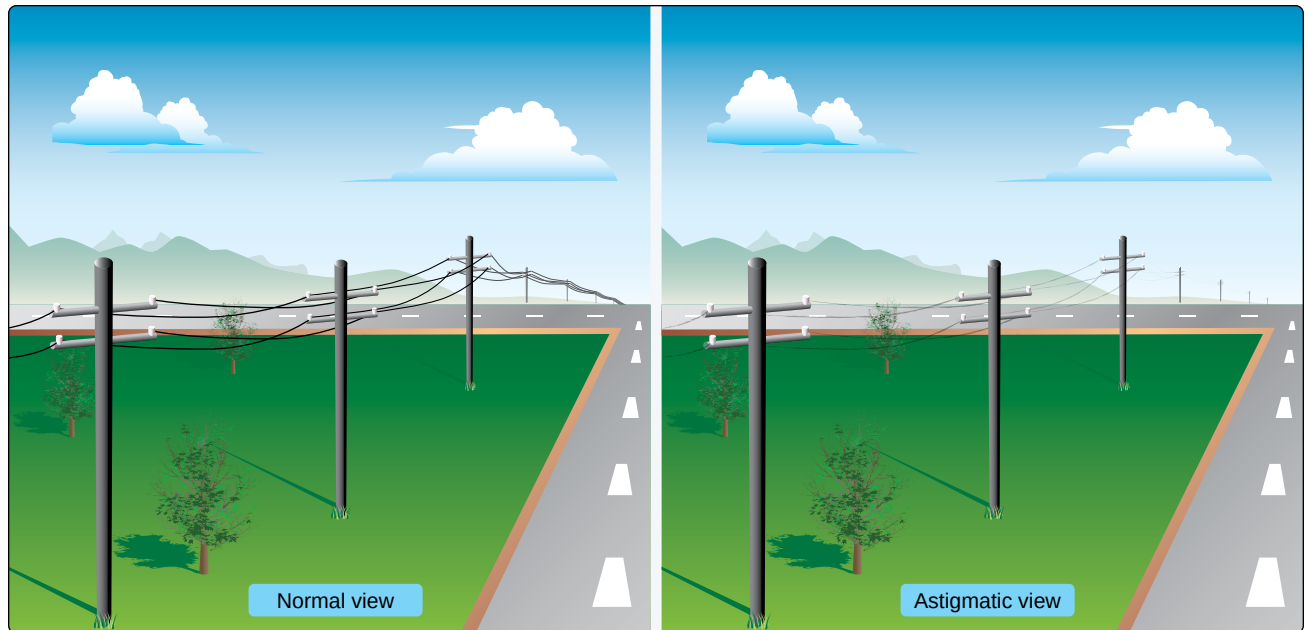


Figure 12-2. Example of a view that might be experienced by someone with astigmatism.

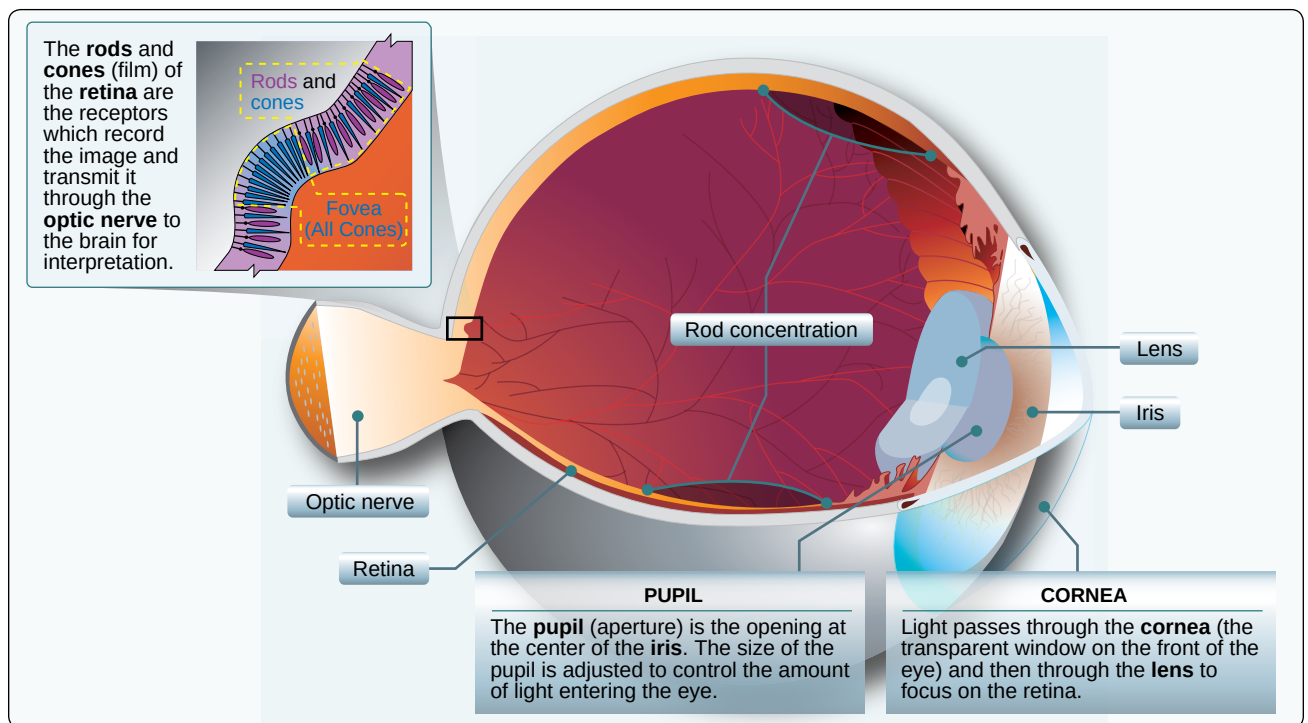


Figure 12-3. The human eye.

a camera. A camera is able to focus on near and far objects by changing the distance between the lens and the film. With the eye on the other hand, objects can be seen clearly at various distances because the shape of its lens is changed automatically by small muscles.

Visual Acuity

Normal visual acuity, or sharpness, is 20/20. A value of 20/80 indicates that an individual reads at 20 feet the letters that an individual with normal acuity (20/20) reads at 80 feet away. The human eye functions like a camera. It has

an instantaneous field of view, which is oval and typically measures 120° vertically by 150° horizontally. When both eyes are used for viewing, the overall field of vision measures about 120° vertically by 200° horizontally.

The Eye

Vision is primarily the result of light striking a photosensitive layer, called the retina, at the back of the eye. The retina is composed of light-sensitive cones and rods. The cones in the eye perceive an image best when the light is bright, while the rods work best in low light. The pattern of light that strikes the cones and rods is transmitted as electrical impulses by the optic nerve to the brain where these signals are interpreted as an image.

Cones

Cones are concentrated around the center of the retina. They gradually diminish in number as the distance from the center increases. Cones allow color perception by sensing red, blue, and green light. Directly behind the lens, on the retina, is a small, notched area called the fovea. This area contains only a high concentration of cone receptors. The best vision in daylight is obtained by looking directly at the object. This focuses the image on the fovea, where detail is best seen. The cones, however, do not function well in darkness, which explains why color is not seen as vividly at night as it is during the day.

Rods

Concentrated outside the fovea area, the rods are the dim light and night receptors. The number of rods increases as the distance from the fovea increases. Rods sense images only in black and white. Because the rods are not located directly behind the pupil, they are responsible for most peripheral vision. Images that move are perceived more easily by the rod areas than by the cones in the fovea. If you have ever seen something move out of the corner of your eye, it was most likely detected by rod receptors.

In low light, the cones lose much of their function, while rods become more receptive. The eye sacrifices sharpness for sensitivity. The ability to see an object directly in front of you is reduced, and much depth perception is lost, as well as judgment of size. The concentration of cones in the fovea can make a night blindspot at the center of vision. How well a person sees at night is determined by the rods in the eyes, as well as by the amount of light allowed into the eyes. At night, the wider the pupil is open at night, the better night vision becomes.

Night Vision

Diet and general physical health have an impact on how well a person can see in the dark. Deficiencies in vitamins A and C have been shown to reduce night acuity. Other factors, such as carbon monoxide poisoning, smoking, alcohol, and certain drugs can greatly decrease night vision. Lack of oxygen can also decrease night vision as the eye requires more oxygen per unit weight than any other part of the body.

Night Scanning

Good night visual acuity is needed for collision avoidance. Night scanning, like day scanning, uses a series of short, regularly spaced eye movements in 10° sectors. Unlike day scanning, however, off-center viewing is used to focus objects on the rods rather than the fovea blindspot. [Figure 12-4] When looking at an object, avoid staring at it too long. If staring at an object without moving the eyes, the retina becomes accustomed to the light intensity and the image begins to fade. To keep it clearly visible, new areas in the retina must be exposed to the image. Small, circular eye movements help eliminate the fading. Also, move the eyes more slowly from sector to sector than during the day to prevent blurring.

During daylight, objects can be perceived at a great distance with good detail. At night, range is limited, and detail is poor. Objects along the flight path can be more readily identified at night, by using the proper techniques to scan the terrain. To

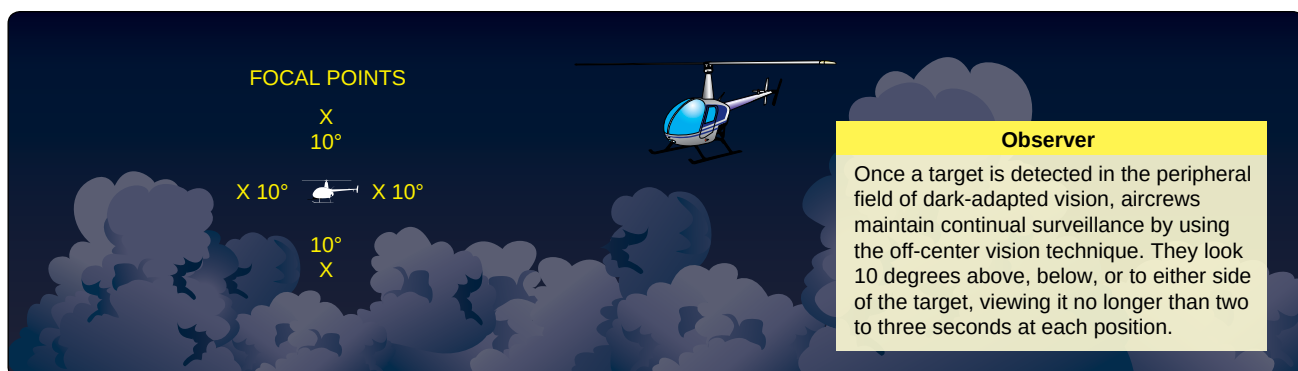


Figure 12-4. Off-center vision technique.

scan effectively, pilots look from side to side. They should begin scanning at the greatest distance at which an object can be perceived high on the horizon, then moving inward toward the position of the aircraft. *Figure 12-5* shows this scanning pattern. Because the light-sensitive elements of the retina are unable to perceive images that are in motion, a stop-turn-stop-turn motion should be used. For each stop, an area about 30 degrees wide should be scanned. This viewing angle includes an area about 250 meters wide at a distance of 500 meters. The duration of each stop is based on the degree

of detail that is required, but no stop should last more than two or three seconds. When moving from one viewing point to the next, pilots should overlap the previous field of view by 10 degrees. This scanning technique allows greater clarity in observing the periphery. Other scanning techniques, as illustrated in *Figure 12-6*, may be developed to fit the situation.

Obstruction Detection

Obstructions having poor reflective surfaces, such as wires and small tree limbs, are difficult to detect. The best way to

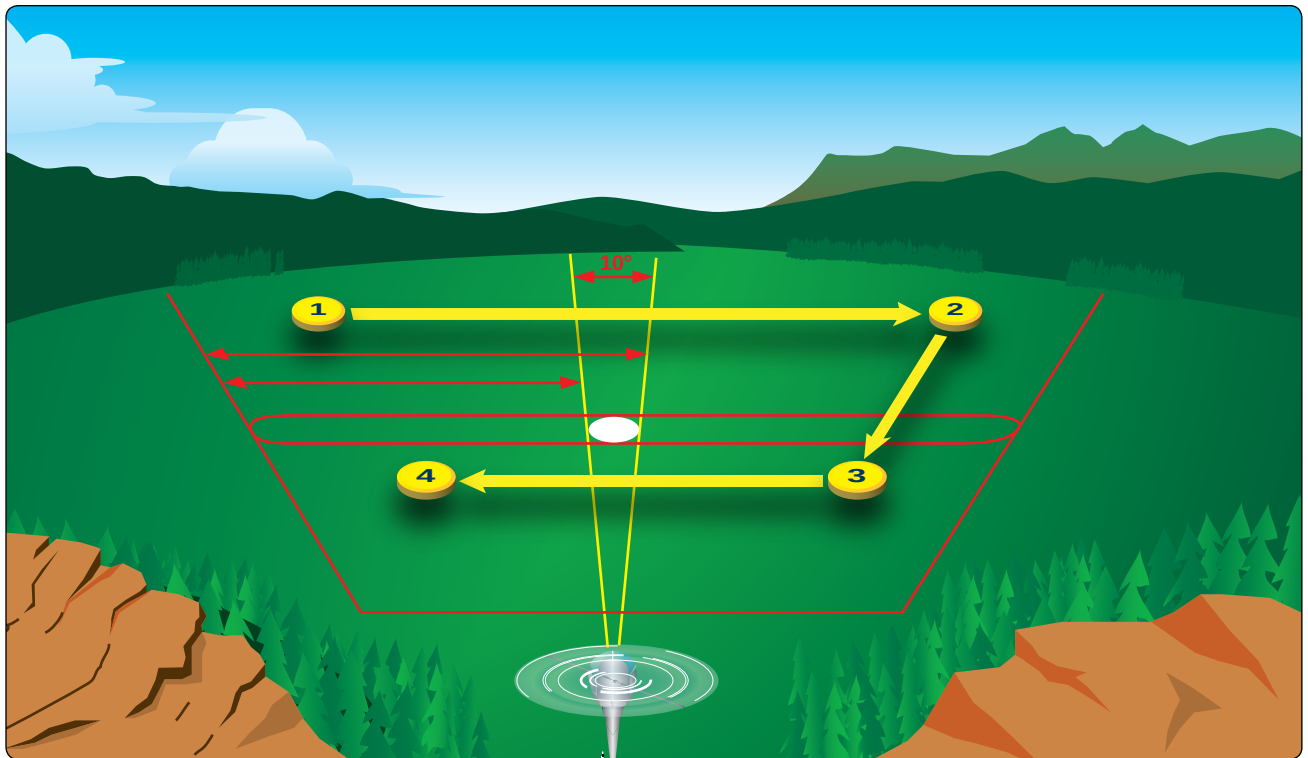


Figure 12-5. *Scanning pattern.*

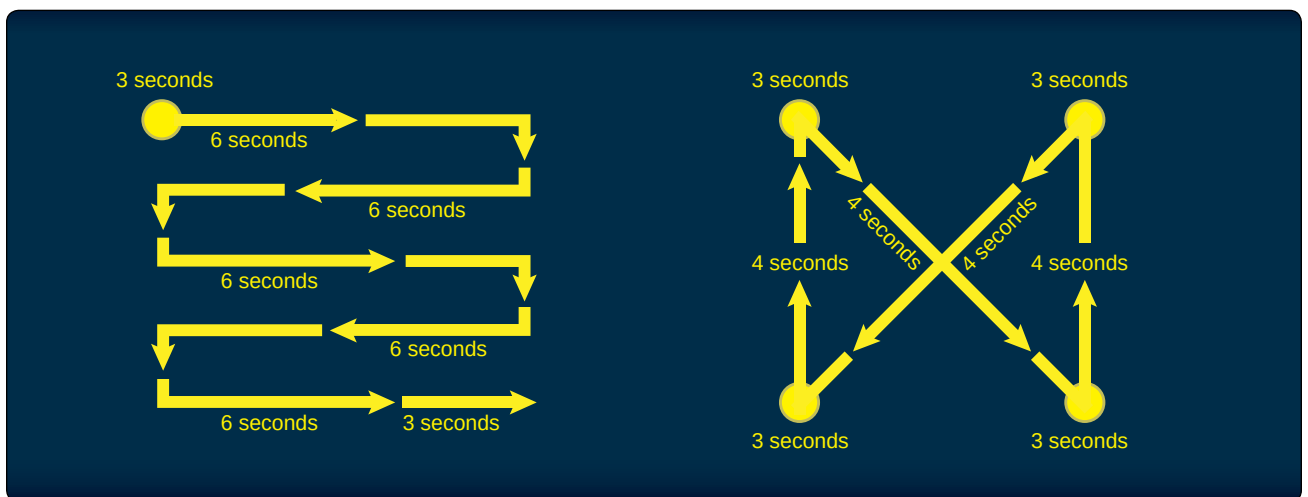


Figure 12-6. *Night vision.*

locate wires is by looking for the support structures. However, pilots should review the most current hazard maps with known wire locations before night flights.

Aircraft Lighting

In order to see other aircraft more clearly, regulations require that all aircraft operating during the night hours have special lights and equipment. The requirements for operating at night are found in Title 14 of the Code of Federal Regulations (14 CFR) part 91. In addition to aircraft lighting, the regulations also provide a definition of night flight in accordance with 14 CFR part 91, currency requirements, fuel reserves, and necessary electrical systems.

Position lights enable a pilot to locate another aircraft, as well as help determine its direction of flight. The approved aircraft lights for night operations are a green light on the right cabin side or wingtip, a red light on the left cabin side or wingtip, and a white position light on the tail. In addition, flashing aviation red or white anticollision lights are required for all flights, if equipped on the aircraft and in an operable condition (in accordance with 14 CFR Section 91.209(b), which aids in the identification during night conditions). These flashing lights can be in a number of locations but are most commonly found on the top and bottom of the cabin.

Figure 12-7 shows examples of aircraft lighting. By interpreting the position lights on other aircraft, the pilot in aircraft 3 can determine whether the aircraft is flying in the opposite direction or is on a collision course. If a red position light is seen to the right of a green light, such as shown by aircraft 1, it is flying toward aircraft 3. A pilot should watch this aircraft closely and be ready to change course. Aircraft 2,

on the other hand, is flying away from aircraft 3, as indicated by the white position light.

Visual Illusions

Illusions give false impressions or misconceptions of actual conditions; therefore, pilots must understand the type of illusions that can occur and the resulting disorientation. Although the eye is the most reliable of the senses, some illusions can result from misinterpreting what is seen; what is perceived is not always accurate. Even with the references outside the cockpit and the display of instruments inside, pilots must be on guard to interpret information correctly.

Relative-Motion Illusion

Relative motion is the falsely perceived self-motion in relation to the motion of another object. The most common example is as follows. An individual in a car is stopped at a traffic light and another car pulls alongside. The individual who was stopped at the light perceives the forward motion of the second car as his or her own motion rearward. This results in the individual applying more pressure to the brakes unnecessarily. This illusion can be encountered during flight in situations such as formation flight, hover taxi, or hovering over water or tall grass.

Confusion with Ground Lights

Confusion with ground lights occurs when a pilot mistakes ground lights for stars. The pilot can place the helicopter in an extremely dangerous flight attitude if he or she aligns it with the wrong lights. In *Figure 12-8A*, the helicopter is aligned with a road and not with the horizon. Isolated ground lights can appear as stars and could lead to the illusion that the helicopter is in a nose-high attitude.

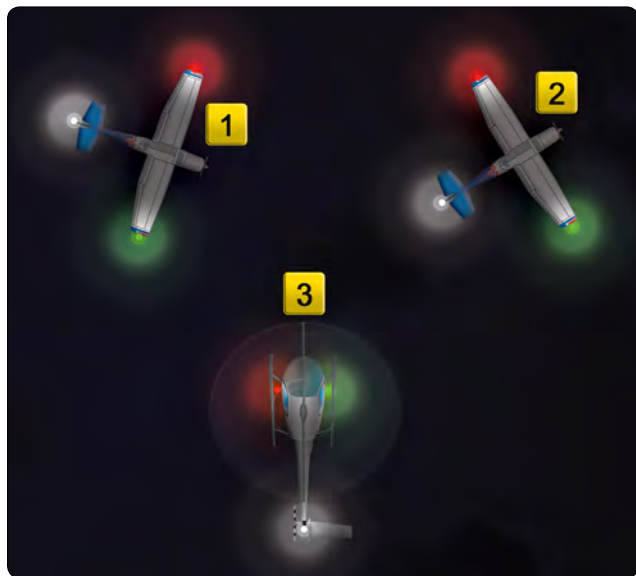


Figure 12-7. Aircraft position lights.

When no stars are visible because of overcast conditions, unlighted areas of terrain can blend with the dark overcast to create the illusion that the unlighted terrain is part of the sky in *Figure 12-8B*. In this illusion, the shoreline is mistaken for the horizon. In an attempt to correct for the apparent nose-high attitude, a pilot may lower the collective and attempt to fly “beneath the shore.” This illusion can be avoided by referencing the flight instruments and establishing a true horizon and attitude.

Reversible Perspective Illusion

At night, an aircraft or helicopter may appear to be moving away when it is actually approaching. If the pilot of each aircraft has the same assumption, and the rate of closure is significant, by the time each pilot realizes his or her own error in assumption, it may be too late to avoid a mishap. This illusion is called reversible perspective and is often experienced when a pilot observes another aircraft

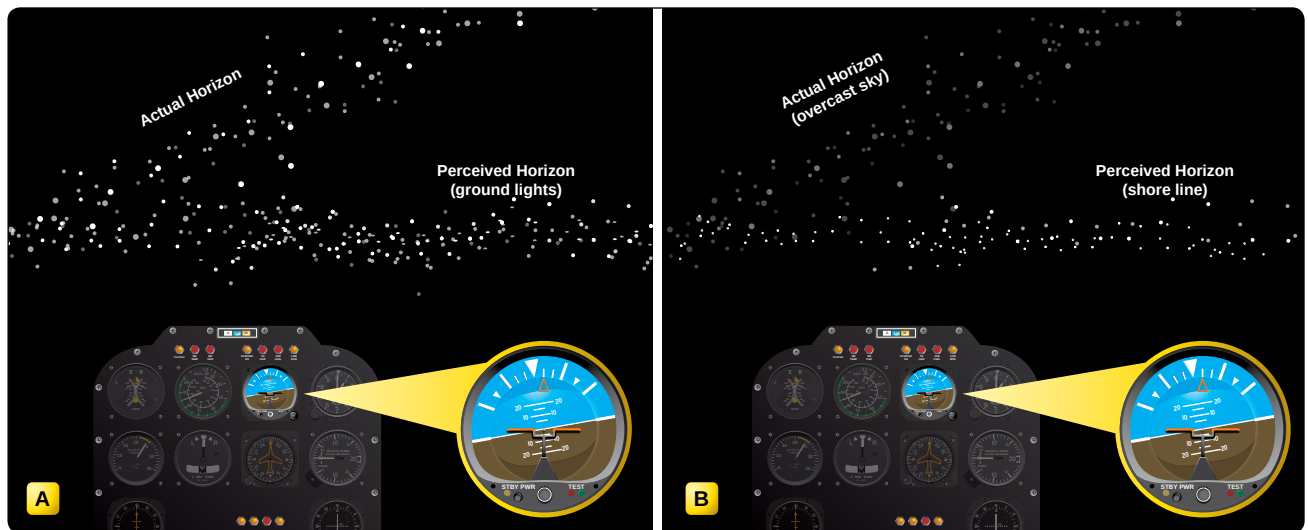


Figure 12-8. At night, the horizon may be hard to discern due to dark terrain and misleading light patterns on the ground.

or helicopter flying an approaching, parallel course. To determine the direction of flight, the pilot should observe the other aircraft's position lights. Remember the following: red on right returning; that is, if an aircraft is seen with the red position light on the right and the green position light on the left, the observed aircraft is traveling in the opposite direction.

Flicker Vertigo

Flicker vertigo is technically not an illusion; however, as most people are aware from personal experience, viewing a flickering light can be both distracting and annoying. Flicker vertigo may be created by helicopter rotor blades or airplane propellers interrupting direct sunlight at a rate of 4 to 20 cycles per second. Flashing anticollision strobe lights, especially while the aircraft is in the clouds, can also produce this effect. One should also be aware that photic stimuli at certain frequencies could produce seizures in those rare individuals who are susceptible to flicker-induced epilepsy.

Night Flight

The night flying environment and the techniques used when flying at night depend on outside conditions. Flying on a bright, clear, moonlit evening when the visibility is good, and the wind is calm is not much different from flying during the day. However, if flying on an overcast night over a sparsely populated area, with few or no outside lights on the ground, the situation is quite different. Visibility is restricted, so be more alert in steering clear of obstructions and low clouds. Options are also limited in the event of an emergency, as it is more difficult to find a place to land and determine wind direction and speed. At night, rely more heavily on the aircraft systems, such as lights, flight instruments, and navigation equipment. As a precaution, if visibility is limited or outside references are inadequate, strongly consider delaying the

flight until conditions improve, unless proper instrument flight training has been received and the helicopter has the appropriate instrumentation and equipment.

Preflight

Aircraft preflight inspection is a critical aspect of flight safety. It must comply with the appropriate rotorcraft flight manual (RFM). Preflight should be scheduled as early as possible in the flight planning sequence, preferably during daylight hours, allowing time for maintenance assistance and correction. If a night preflight is necessary, a flashlight with an unfiltered lens (white light) should be used to supplement lighting. Oil and hydraulic fluid levels and leaks are difficult to detect with a blue-green or red lens. Windscreens should be checked to ensure they are clean and relatively free of scratches. Slight scratches are acceptable for day flight but may not be for night flight. The search light or landing light should be positioned for the best possible illumination during an emergency descent.

Careful attention must be paid to the aircraft electrical system. In helicopters equipped with fuses, a spare set is required by regulation, and by common sense, so make sure they are on board. If the helicopter is equipped with circuit breakers, check to see that they are not tripped. A tripped circuit breaker may be an indication of an equipment malfunction and should be left for maintenance to troubleshoot before flying.

All aircraft operating between sunset and sunrise are required to have operable navigation (position) lights. Turn these lights on during the preflight to inspect them visually for proper operation. Between sunset and sunrise, these lights must be on any time the helicopter is operating.

All recently manufactured aircraft certificated for night flight must have an anticollision light that makes the aircraft more visible to other pilots. This light is either a red or white flashing light and may be in the form of a rotating beacon or a strobe. While anticollision lights are required for night visual flight rules (VFR) flights, they may be turned off any time they create a distraction for the pilot.

One of the first steps in preparation for night flight is to become thoroughly familiar with the helicopter's cockpit, instrumentation, and control layout. It is recommended that a pilot practice locating each instrument, control, and switch, both with and without cabin lights. Since the markings on some switches and circuit breaker panels may be difficult to read at night, be able to locate and use these devices, and read the markings in poor light conditions. Before starting the engine, make sure all necessary equipment and supplies needed for the flight, such as charts, notepads, and flashlights, are accessible and ready for use.

Cockpit Lights

Check all interior lights with special attention to the instrument and panel lights. The panel lighting can usually be controlled with a rheostat or dimmer switch, allowing the pilot to adjust the intensity. If a particular light is too bright or causes reflection or glare off the windshield, it should be adjusted or turned off. As ambient light level decreases from twilight to darkness, intensity of the cockpit lights is reduced to a low, usable intensity level that reduces any glare or reflection off the windshield. The light level should be adjusted to as close to the ambient light level as possible. A flashlight, with red or blue-green lens filter, or map light can supplement the available light in the cockpit. Always carry a flashlight with fresh batteries to provide an alternate source of light if the interior lights malfunction. If an existing map/utility light is used, it should be hand-held or remounted to a convenient location. In order to retain night adaptation, use low level light when using your checklist. Brief your passengers on the importance of light discipline during night flight so the pilot is not blinded, causing loss of dark adaptation.

Engine Starting and Rotor Engagement

Use extra caution when starting the engine and engaging the rotors, especially in dark areas with little or no outside lights. In addition to the usual call of "clear," turn on the position and anticollision lights. If conditions permit, also turn the landing light on momentarily to help warn others that the engine is about to start and engage the rotors.

Taxi Technique

Landing lights usually cast a beam that is narrow and concentrated ahead of the helicopter, so illumination to the side is minimal. Therefore, slow the taxi at night, especially

in congested ramp and parking areas. Some helicopters have a hover light in addition to a landing light, which illuminates a larger area under the helicopter.

When operating at an unfamiliar airport at night, ask for instructions or advice concerning local conditions, so as to avoid taxiing into areas of construction, or unlighted, unmarked obstructions. Ground controllers or UNICOM operators are usually cooperative in furnishing this type of information.

Night Traffic Patterns

Traffic patterns are covered in Chapter 9, Basic Flight Maneuvers, but the following additional considerations should be taken into account when flying a helicopter in a night traffic pattern:

1. The minimum recommended pattern height at night is 1,000 feet when able.
2. If possible, consider taking the right hand night pattern with fixed wing in the left hand pattern for extra separation, but if needed, conform and integrate with the fixed wing using the same pattern height.
3. Be extra vigilant on abiding with noise abatement procedures at night.
4. Always plan to use the lit runway at night for unaided (no night vision equipment) approaches and departures.
5. Avoid downwind and crosswind approaches at night when able.

Takeoff

Before takeoff, make sure that there is a clear, unobstructed takeoff path. At airports, this is accomplished by taking off over a runway or taxi way, however, if operating off-airport, pay more attention to the surroundings. Obstructions may also be difficult to see if taking off from an unlighted area. Once a suitable takeoff path is chosen, select a point down the takeoff path to use for directional reference. The landing light should be positioned in order to illuminate the tallest obstacles in the takeoff path. During a night takeoff, notice a lack of reliable outside visual references after becoming airborne. This is particularly true at small airports and off-airport landing sites located in sparsely populated areas. To compensate for the lack of outside references, use the available flight instruments as an aid. Check the altimeter and the airspeed indicator to verify the proper climb attitude. An attitude indicator, if installed, can enhance attitude reference.

The first 500 feet of altitude after takeoff is considered to be the most critical period in transitioning from the comparatively well-lit airport or heliport into what sometimes appears to be

total darkness. A takeoff at night is usually an “altitude over airspeed” maneuver, meaning a pilot most likely performs a nearly maximum performance takeoff. This improves the chances for obstacle clearance and enhances safety.

En Route Procedures

In order to provide a higher margin of safety, it is recommended that a cruising altitude somewhat higher than normal be selected. There are three reasons for this. First, a higher altitude gives more clearance between obstacles, especially those that are difficult to see at night, such as high-tension wires and unlighted towers. Second, in the event of an engine failure, there is more time to set up for a landing and the greater gliding distance gives more options for a safe landing. Third, radio reception is improved, particularly if using radio aids for navigation.

During preflight planning, when possible, it is recommended that a route of flight be selected that is within reach of an airport, or any safe landing site. It is also recommended that pilots fly as close as possible to a populated or lighted area, such as a highway or town. Not only does this offer more options in the event of an emergency, but also makes navigation a lot easier. A course comprised of a series of slight zigzags to stay close to suitable landing sites and well-lit areas, only adds a little more time and distance to an otherwise straight course.

In the event of a forced landing at night, use the same procedure recommended for day time emergency landings. If available, turn on the landing light during the final descent to help in avoiding obstacles along the approach path.

Collision Avoidance at Night

Because the quantity and quality of outside visual references are greatly reduced, a pilot tends to focus on a single point or instrument, making him or her less aware of the other traffic around. Make a special effort to devote enough time to scan for traffic. As discussed previously in this chapter, effective scanning is accomplished with a series of short, regularly spaced eye movements that bring successive areas of the sky into the central visual field. Contrary to the 30-degree scan used to view the ground in the case of scanning for other aircraft, each movement in this case should not exceed 10 degrees, and each area should be observed for at least 1 second to enable detection. If the pilot detects a dimly lit object in a certain direction, the pilot should not look directly at the object, but scan the area adjacent to it, called off-center viewing. This will decrease the chances of fixating on the light and allow focusing more on the objects (e.g., tower, aircraft, ground lights). Short stops of a few seconds in duration in each scan will help to detect the light and its movement. A pilot can determine

another aircraft’s direction of flight by interpreting the position and anticollision lights, as previously described. When scanning, pilots should also remember to move their heads, not just their eyes. Ground obstructions can cover a considerable amount of sky, and the area can easily be uncovered by a small head movement.

Approach and Landing

Night approaches and landings do have some advantages over daytime approaches, as the air is generally smoother, and the disruptive effects of turbulence and excessive crosswinds are often absent. However, there are a few special considerations and techniques that apply to approaches at night. For example, when landing at night, especially at an unfamiliar airport, make the approach to a lighted runway and then use the taxiways to avoid unlighted obstructions or equipment.

Carefully controlled studies have revealed that pilots have a tendency to make lower approaches at night than during the day. This is potentially dangerous as there is a greater chance of hitting an obstacle, such as an overhead wire or fence, that is difficult to see. It is good practice to make steeper approaches at night, increasing the probability of clearing obstacles. Monitor altitude and rate of descent using the altimeter.

Another pilot tendency during night flight is to focus too much on the landing area and not pay enough attention to airspeed. If too much airspeed is lost, a vortex ring state condition may result. Maintain the proper attitude during the approach, and ensure that you keep some forward airspeed and movement until close to the ground. Outside visual references for airspeed and rate of closure may not be available, especially when landing in an unlit area, so pay special attention to the airspeed indicator.

Although the landing light is a helpful aid when making night approaches, there is an inherent disadvantage. The portion of the landing area illuminated by the landing light seems higher than the dark area surrounding it. This effect can cause a pilot to terminate the approach at an altitude that is too high, which may result in a vortex ring state condition and a hard landing.

Illusions Leading to Landing Errors

Various surface features and atmospheric conditions encountered in night landing can create illusions of incorrect height above and distance from the runway threshold. Landing errors from these illusions can be prevented by anticipating them during approaches, conducting an aerial visual inspection of unfamiliar airports before landing, using electronic glideslope or VASI systems when available, and maintaining optimum proficiency in landing procedures.

Featureless Terrain Illusion

An absence of ground features, as when landing over water, darkened areas, and terrain made featureless by snow, can create the illusion that the aircraft is at a higher altitude than it actually is. The pilot who does not recognize this illusion will fly a lower approach.

Atmospheric Illusions

Rain on the windscreen can create the illusion of greater height, and atmospheric haze can create the illusion of being at a greater distance from the runway. The pilot who does not recognize these illusions flies a higher approach. Penetration of fog can create the illusion of pitching up. The pilot who does not recognize this illusion steepens the approach, often quite abruptly.

Ground Lighting Illusions

Lights along a straight path can be mistaken for runway and approach lights. This might include street lights along a roadside or even the internal lights of a moving train. Another illusion may occur with very intense runway and approach lighting. Due to the relative brightness of these lights, the pilot may perceive them to be closer than they really are. Assuming that the lights are as close as they appear, the pilot may attempt an approach that is actually lower than glideslope. Conversely, the pilot flying over terrain with few lights may make a lower than normal approach.

Helicopter Night VFR Operations

While ceiling and visibility significantly affect safety in night VFR operations, lighting conditions also have a profound effect on safety. Even in conditions in which visibility and ceiling are determined to be visual meteorological conditions, the ability to discern unlit or low contrast objects and terrain at night may be compromised. The ability to discern these objects and terrain is referred to as the “seeing condition,” and is related to the amount of natural and man-made lighting available, and the contrast, reflectivity, and texture of surface terrain and obstruction features. In order to conduct operations safely, seeing conditions must be accounted for in the planning and execution of night VFR operations.

Night VFR seeing conditions can be described by identifying high lighting conditions and low lighting conditions.

High lighting conditions exist when one of two sets of conditions are present:

1. The sky cover is less than broken (less than $\frac{5}{8}$ cloud cover), the time is between the local moon rise and moon set, and the lunar disk is at least 50 percent illuminated; or

2. The aircraft is operated over surface lighting that, at least, provides lighting of prominent obstacles, the identification of terrain features (shorelines, valleys, hills, mountains, slopes) and a horizontal reference by which the pilot may control the helicopter. For example, this surface lighting may be the result of:
 - a. Extensive cultural lighting (manmade, such as a built-up area of a city),
 - b. Significant reflected cultural lighting (such as the illumination caused by the reflection of a major metropolitan area’s lighting reflecting off a cloud ceiling), or
 - c. Limited cultural lighting combined with a high level of natural reflectivity of celestial illumination, such as that provided by a surface covered by snow or a desert surface.

Low lighting conditions are those that do not meet the high lighting conditions requirements.

Some areas may be considered a high lighting environment only in specific circumstances. For example, some surfaces, such as a forest with limited cultural lighting, normally have little reflectivity, requiring dependence on significant moonlight to achieve a high lighting condition. However, when that same forest is covered with snow, its reflectivity may support a high lighting condition based only on starlight. Similarly, a desolate area, with little cultural lighting, such as a desert, may have such inherent natural reflectivity that it may be considered a high lighting conditions area regardless of season, provided the cloud cover does not prevent starlight from being reflected from the surface. Other surfaces, such as areas of open water, may never have enough reflectivity or cultural lighting to ever be characterized as a high lighting area.

Through the accumulation of night flying experience in a particular area, the pilot develops the ability to determine, prior to departure, which areas can be considered supporting high or low lighting conditions. Without that pilot experience, low lighting considerations should be applied by pilots for both preflight planning and operations until high lighting conditions are observed or determined to be regularly available. Even if the aircraft is certified for day and night VFR conditions, night flight should only be conducted if adequate celestial illumination is assured during the entirety of the flight.

Chapter Summary

Knowledge of the basic anatomy and physiology of the eye is helpful in the study of helicopter night operations. Adding

to that knowledge a study of visual illusions gives the pilot ways to overcome those illusions. Techniques for preflight, engine start-up, collision avoidance, and night approach and landings help teach the pilot safer ways to conduct flight at night. More detailed information on the subjects discussed in this chapter is available in the Aeronautical Information Manual (AIM) and online at www.faa.gov.

Chapter 13

Effective Aeronautical Decision-Making

Introduction

The accident rate for helicopters has traditionally been higher than the accident rate of fixed-wing aircraft, probably due to the helicopter's unique capabilities to fly and land in more diverse situations than fixed-wing aircraft and pilot attempts to fly the helicopter beyond the limits of his or her abilities or beyond the capabilities of the helicopter. With no significant improvement in helicopter accident rates for the last 20 years, the Federal Aviation Administration (FAA) has joined with various members of the helicopter community to improve the safety of helicopter operations.

According to National Transportation Safety Board (NTSB) statistics, approximately 80 percent of all aviation accidents are caused by pilot error, the human factor. Many of these accidents are the result of the failure of instructors to incorporate single-pilot resource management (SRM) and risk management into flight training instruction of aeronautical decision-making (ADM).

SRM is defined as the art of managing all the resources (both on board the aircraft and from outside sources) available to a pilot prior to and during flight to ensure a successful flight. When properly applied, SRM is a key component of ADM. Additional discussion includes integral topics such as, the concepts of risk management, workload or task management, situational awareness, controlled flight into terrain (CFIT) awareness, and automation management.



Pilot

The pilot's fitness to fly must be evaluated, including competency in the helicopter, currency, and flight experience.

Task

The pilot's task must be evaluated, including the complexity of the task and the pilot's ability to perform the task.

Factors

Factors such as weather, airport conditions, and aircraft condition must be examined.

Decision

The pilot's decision must be evaluated, including the pilot's ability to make a decision and the pilot's ability to execute the decision.

Situation

To maintain situational awareness, an accurate understanding of the helicopter's position and the surrounding environment is essential.

ADM is all about learning how to gather information, analyze it, and make decisions. It helps the pilot accurately assess and manage risk and make accurate and timely decisions. Although the flight is coordinated by a single person, the use of available resources, such as air traffic control (ATC) and flight service stations (FSS)/automated flight service stations (AFSS), replicates the principles of crew resource management (CRM) (see page 14-7).

References on SRM and ADM include:

- FAA-H-8083-2, Risk Management Handbook.
- Aeronautical Information Manual (AIM).
- Advisory Circular (AC) 60-22, Aeronautical Decision Making, which provides background information about ADM training in the general aviation (GA) environment.
- FAA-H-8083-25, Pilot's Handbook of Aeronautical Knowledge.

Aeronautical Decision-Making (ADM)

Making good choices sounds easy enough. However, there are a multitude of factors that come into play when these choices, and subsequent decisions, are made in the aeronautical world. Many tools are available for pilots to become more self-aware and assess the options available, along with the impact of their decision. Yet, with all the available resources, accident rates are not being reduced. Poor decisions continue to be made, frequently resulting in lives being lost and/or aircraft damaged or destroyed. The Risk Management Handbook discusses ADM and SRM in detail and should be thoroughly read and understood.

While progress is continually being made in the advancement of pilot training methods, aircraft equipment and systems, and services for pilots, accidents still occur. Historically, the term “pilot error” has been used to describe the causes of these accidents. Pilot error means an action or decision made by the pilot was the cause of, 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. *[Figure 13-1]*

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 is often the only event necessary to change the outcome of the sequence of events. The following is an example of the type of scenario illustrating the poor judgment chain.

Scenario

A Helicopter Air Ambulance (HAA) pilot is nearing the end of his shift when he receives a request for a patient pickup at a roadside vehicle accident. The pilot has started to feel the onset of a cold; his thoughts are on getting home and getting a good night’s sleep. After receiving the request, the pilot checks the accident location and required flightpath to determine if he has time to complete the flight to the scene, then on to the hospital before his shift expires. The pilot checks the weather and determines that, although thunderstorms are approaching, the flight can be completed prior to their arrival.

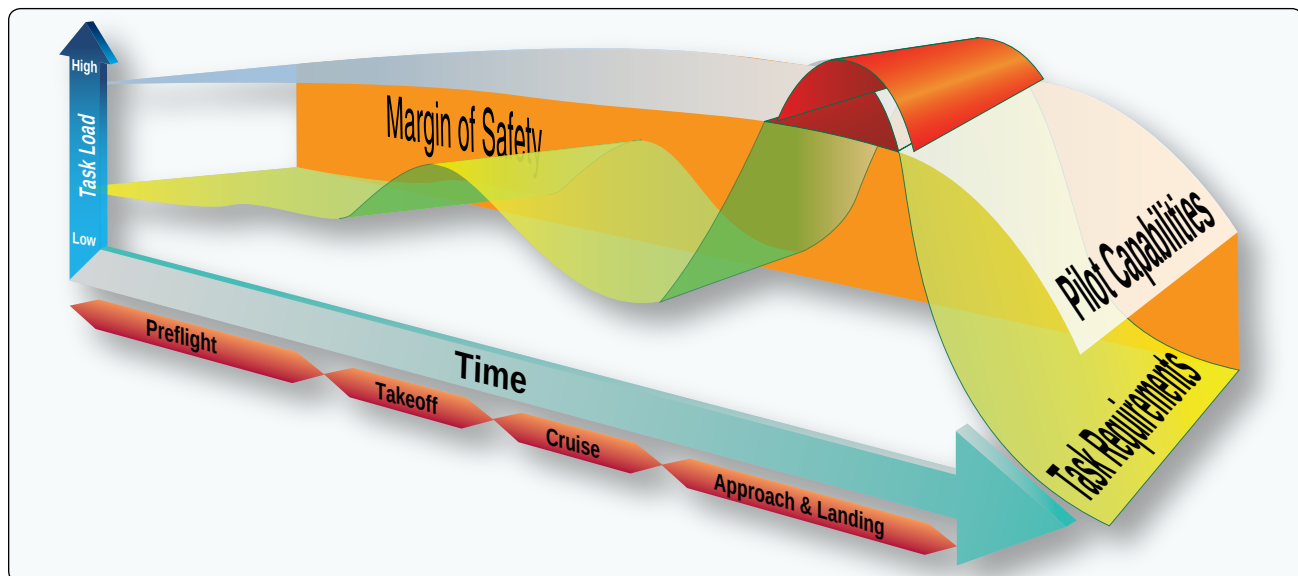


Figure 13-1. The pilot has a limited capacity of doing work and handling tasks, meaning there is a point at which the tasking exceeds the pilot’s capability. When this happens, either tasks are not done properly or some are not done at all.

The pilot and on-board medical crews depart the home location and arrive overhead, at the scene of the vehicular accident. The pilot is not comfortable with the selected landing area due to tall trees in all quadrants of the confined area. The pilot searches for a secondary landing area. Unable to find one nearby, the pilot then returns to the initial landing area and decides he can make it work.

After successfully landing the aircraft, he is told that there will be a delay before the patient is loaded because more time is needed to extricate the patient from the wreckage. Knowing his shift is nearly over, the pilot begins to feel pressured to “hurry up” or he will require an extension for his duty day.

After 30 minutes, the patient is loaded, and the pilot ensures everyone is secure. He notes that the storm is now nearby and that winds have picked up considerably. The pilot thinks, “No turning back now, the patient is on board and I’m running out of time.” The pilot knows he must take off almost vertically to clear the obstacles and chooses his departure path based on the observed wind during landing. Moments later, prior to clearing the obstacles, the aircraft begins an uncontrollable spin and augers back to the ground, seriously injuring all on board and destroying the aircraft.

What could the pilot have done differently to break this error chain? More important—what would you have done differently? By discussing the events that led to this accident, you should develop an understanding of how a series of judgmental errors contributed to the final outcome of this flight.

For example, the pilot’s decision to fly the aircraft knowing that the effects of an illness were present was the initial contributing factor. The pilot was aware of his illness, but, was he aware of the impact of the symptoms—fatigue, general uneasy feeling due to a slight fever, perhaps?

Next, knowing the shift was about to end, the pilot based his time required to complete the flight on ideal conditions, and did not take into consideration the possibility of delays. This led to a feeling of being time limited.

Even after determining the landing area was unsuitable, the pilot forced the landing due to time constraints. At any time during this sequence, the pilot could have aborted the flight rather than risk crew lives. Instead, the pilot became blinded by a determination to continue.

After landing, and waiting 30 minutes longer than planned, the pilot observed the outer effects of the thunderstorm, yet still attempted to depart. The pilot dispelled any available options by thinking the only option was to go forward; however, it would have been safer to discontinue the flight.

Using the same departure path selected under different wind conditions, the pilot took off and encountered winds that led to loss of aircraft control. Once again faced with a self-imposed time constraint, the pilot improperly chose to depart the confined area. The end result: instead of one patient to transport by ground (had the pilot aborted the flight at any point), there were four patients to be transported.

On numerous occasions leading to and during the flight, the pilot could have made effective decisions that could have prevented this accident. However, as the chain of events unfolded, each poor decision left him with fewer options. Making sound decisions is the key to preventing accidents. Traditional pilot training emphasizes flying skills, knowledge of the aircraft, and familiarity with regulations. SRM and ADM training focus on the decision-making process and on the factors that affect a pilot’s ability to make effective choices.

Trescott Tips

Max Trescott, Master Certificated Flight Instructor (CFI) and Master Ground Instructor and winner of the 2008 CFI of the year, has published numerous safety tips that every pilot should heed. He believes that the word “probably” should be purged from our flying vocabulary. Mr. Trescott contends that “probably” means we’ve done an informal assessment of the likelihood of an event occurring and have assigned a probability to it. He believes the term implies that we believe things are likely to work out, but there’s some reasonable doubt in our mind. He further explains that if you ever think that your course of action will “probably work out,” you need to choose a new option that you know will work out.

Another safety tip details the importance of accumulating flight hours in one specific airframe type. He explains that “statistics have shown that accidents are correlated more with the number of hours of experience a pilot has in a particular aircraft model and not with his or her total number of flight hours. Accidents tend to decrease after a pilot accumulates at least 100 hours of experience in the aircraft he or she is flying. Thus, when learning to fly, or when transitioning into a new model, your goal should be to concentrate your flying hours in that model.” He suggests waiting until you reach 100 hours of experience in one particular model before attempting a dual rating with another model. In addition, if you only fly a few hours per year, maximize your safety by concentrating those hours in just one aircraft model.

The third safety tip that is well worth mentioning is what Mr. Trescott calls “building experience from the armchair.” Armchair flying is simply closing your eyes and mentally practicing exactly what you do in the aircraft. This is an excellent way to practice making radio calls, departures, approaches and even visualizing the parts and pieces of the

aircraft. This type of flying does not cost a dime and will make you a better prepared and more proficient pilot.

All three of Max Trescott's safety tips incorporate the ADM process and emphasize the importance of how safety and good decision-making is essential to aviation.

The Decision-Making Process

An understanding of the decision-making process provides a pilot with a foundation for developing ADM skills. Some situations, such as engine failures, require a pilot to respond immediately using established procedures with little time for detailed analysis. Called automatic decision-making, it 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 that require a more reflective response when greater analysis is necessary. They often overlook the phase of decision-making that is accomplished on the ground: the preflight, flight planning, performance planning, weather briefing, and weight/center of gravity configurations. Thorough and proper completion of these tasks provides increased awareness and a base of knowledge available to the pilot prior to departure and once airborne. Typically during a flight, a pilot has 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

Defining the problem is the first step in the decision-making process and 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 (self-awareness) and experience. Insight, experience, and objective analysis of all available information are used to determine the exact nature and severity of the problem. One critical error that can be made during the decision-making process is incorrectly defining the problem.

While going through the following example, keep in mind what errors lead up to the event. What planning could have been completed prior to departing that may have led to avoiding this situation? What instruction could the pilot have had during training that may have better prepared the pilot for this scenario? Could the pilot have assessed potential problems based on what the aircraft "felt like" at a hover? All these factors go into recognizing a change and the timely response.

While doing a hover check after picking up firefighters at the bottom of a canyon, a pilot realized that she was only 20 pounds under maximum gross weight. What she failed to realize was that the firefighters had stowed some of their heaviest gear in the baggage compartment, which shifted

the center of gravity (CG) slightly behind the aft limits. Since weight and balance had never created any problems for her in the past, she did not bother to calculate CG and power required. She did try to estimate it by remembering the figures from earlier in the morning at the base camp. At a 5,000-foot density altitude (DA) and maximum gross weight, the performance charts indicated the helicopter had plenty of excess power. Unfortunately, the temperature was 93 °F and the pressure altitude at the pickup point was 6,200 feet (DA = 9,600 feet). Since there was enough power for the hover check, the pilot decided there was sufficient power to takeoff.

Even though the helicopter accelerated slowly during the takeoff, the distance between the helicopter and the ground continued to increase. However, when the pilot attempted to establish the best rate of climb speed, the nose tended to pitch up to a higher-than-normal attitude, and the pilot noticed that the helicopter was not gaining enough altitude in relation to the canyon wall approximately 200 yards ahead.

Choosing a Course of Action

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

The pilot's first thought was to pull up on the collective and pull back on the cyclic. After weighing the consequences of possibly losing rotor revolutions per minute (rpm) and not being able to maintain the climb rate sufficiently to clear the canyon wall, which was then only a hundred yards away, she realized the only course was to try to turn back to the landing zone on the canyon floor.

Implementing the Decision and Evaluating the Outcome

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

As the pilot made the turn to the downwind, the airspeed dropped nearly to zero, and the helicopter became very difficult to control. (At this point, the pilot must increase airspeed in order to maintain translational lift.) Since the CG was aft of limits, she needed to apply more forward cyclic than usual. As she approached the landing zone with a high rate of descent, she realized that she would

be in a potential vortex ring state situation if she tried to trade airspeed for altitude and lost effective translational lift (ETL). Therefore, it did not appear that she would be able to terminate the approach in a hover. The pilot decided to make the shallowest approach possible and perform a run-on landing.

Pilots sometimes have trouble not because of deficient basic skills or system knowledge, but 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) it provides.

Therefore, a poor decision early in a flight can compromise the safety of the flight at a later time. It is important to make appropriate and decisive choices because good decision-making early in an emergency provide greater latitude for later options.

Decision-Making Models

The decision-making process normally consists of several steps before a pilot chooses a course of action. A variety of structured frameworks for decision-making provide assistance in organizing the decision process. These models include but are not limited to the 5P (Plan, Plane, Pilot, Passengers, Programming), the OODA Loop (Observation, Orientation, Decision, Action), and the DECIDE (Detect, Estimate, Choose, Identify, Do, and Evaluate) models. [Figure 13-2] All these models and their variations are discussed in detail in the Pilot's Handbook of Aeronautical Knowledge section covering aeronautical decision-making.

Whichever model is used, the pilot learns how to define the problem, choose a course of action, implement the decision, and evaluate the outcome. Remember, there is no one right answer in this process: a pilot analyzes the situation in light of experience level, personal minimums, and current physical and mental readiness levels, and then makes a decision.

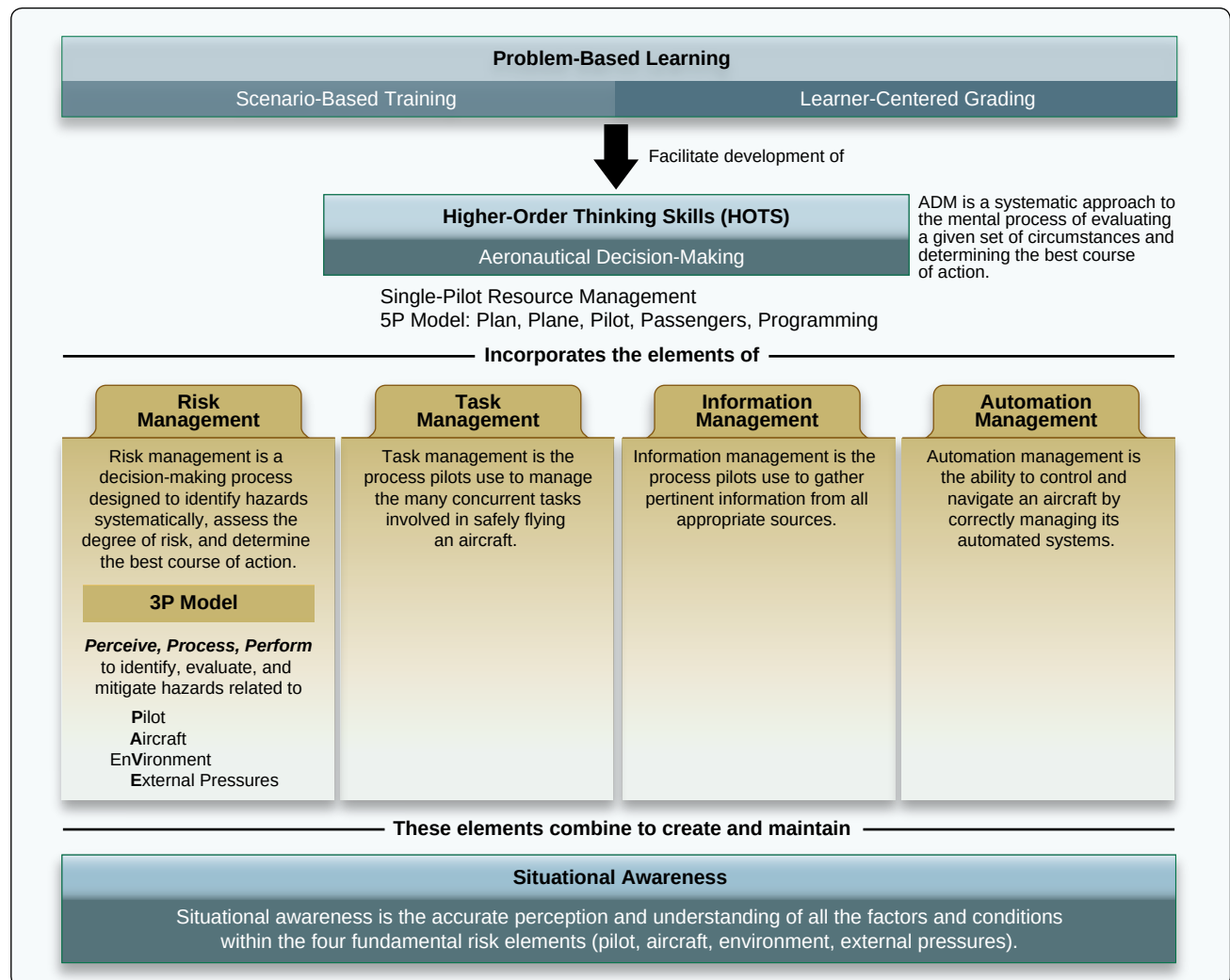


Figure 13-2. Various models of decision-making are used in problem solving.

Pilot Self-Assessment

The pilot in command (PIC) of an aircraft is directly responsible for and is the final authority for the operation of that aircraft. The list of PIC responsibilities is long, and nothing should be overlooked. To exercise those responsibilities effectively and make effective decisions regarding the outcome of a flight, a pilot must have an understanding of personal limitations. Pilot performance from planning the flight to execution of the flight is affected by many factors, such as health, experience, knowledge, skill level, and attitude.

Exercising good judgment begins prior to taking the controls of an aircraft. Often, pilots thoroughly check their aircraft to determine airworthiness, yet do not evaluate their own fitness for flight. Just as a checklist is used when preflighting an aircraft, a personal checklist based on such factors as experience, currency, and comfort level can help determine if a pilot is prepared for a particular flight. Specifying when refresher training should be accomplished and designating weather minimums, which may be higher than those listed in Title 14 of the Code of Federal Regulations (14 CFR) part 91, are elements that may be included on a personal checklist. Over confidence can kill just as fast as inexperience. In addition to a review of personal limitations, a pilot should use the I'M SAFE checklist to further evaluate fitness for flight. [Figure 13-3]

Curiosity: Healthy or Harmful?

The roots of aviation are firmly based on curiosity. Where would we be today had it not been for the dreams of Leonardo da Vinci, the Wright Brothers, and Igor Sikorsky? They all were infatuated with flight, a curiosity that led to the origins of aviation. The tale of aviation is full of firsts: first flight, first helicopter, first trans-Atlantic flight, and so on. But, along the way there were many setbacks, fatalities, and lessons learned.



Figure 13-3. I'M SAFE checklist.

Today, we continue to learn and investigate the limits of aviation. We've been to the moon, and soon beyond. Our curiosity will continue to drive us to search for the next challenge.

However, curiosity can also have catastrophic consequences. Despite over 100 years of aviation practice, we still see accidents that are caused by impaired judgment formed from curious behavior. Pilots commonly seek to determine the limits of their ability as well as the limits of the aircraft. Unfortunately, too often this leads to mishaps with deadly results. Inquisitive behavior must be harnessed and displayed within personal and material limits.

Deadly curiosity may not seem as obvious to some as it is to others. Simple thoughts such as, "Is visibility really as bad as what the ATIS is reporting?" or "Will the 20-minute fuel light really indicate only 20 minutes worth of fuel?" can lead to poor decisions and disastrous outcomes.

Some aviators blatantly violate rules and aircraft limitations without thinking through the consequences. "What indications and change in flight characteristics will I see if I fly this helicopter above its maximum gross weight?" or "I've heard this helicopter can do aerobatic flight. Why is it prohibited?" are examples of extremely harmful curiosity. Even more astounding is their ignoring to the fact that the damage potentially done to the aircraft will probably manifest later in the aircraft's life, affecting other crews. Spontaneous excursions in aviation can be deadly.

Curiosity is natural and promotes learning. Airmen should abide by established procedures until proper and complete hazard assessment and risk management can be completed.

The PAVE Checklist

As found in the Pilot's Handbook of Aeronautical Knowledge, the FAA has designed a personal minimums checklist. To help pilots with self-assessment, which in turn helps mitigate risk, the acronym PAVE divides the risks of flight into four categories. For each category, think of the applicability specific to helicopter operations:

- Pilot (pilot in command)
 - Physical, emotional readiness.
 - Flight experience, recency, currency, total time in type.
- Aircraft
 - Is the helicopter capable of performing the task?
 - Can it carry the necessary fuel?

- Does it provide adequate power margins for the task to be accomplished?
- Can it carry the weight and remain within CG?
- Will there be external loads?
- Environment
 - Helicopters are susceptible to the impact of changing weather conditions.
 - How will the change in moderating temperatures and DA affect performance?
 - Will controllability be jeopardized by winds, terrain, and turbulence?
- External pressures
 - Do not let the notion to accomplish “the mission” override good judgment and safety.
 - Many jobs include time lines. How often do we hear “time is money” or “time is wasting”? Don’t sacrifice safety for an implied or actual need to meet the deadline!
 - Do not allow yourself to feel pressured by coworkers, family events, or friends.

Incorporated into preflight planning, the PAVE checklist provides the pilot with a simple way to remember each category to examine for risk prior to each flight. Once the pilot identifies the risks of a flight, he or she needs to decide whether the risk or combination of risks can be managed safely and successfully. Remember, the PIC is responsible for deciding about canceling the flight. If the pilot decides to continue with the flight, he or she should develop strategies to mitigate the risks.

One way to control risk is by setting personal minimums for items in each risk category. Remember, these are limits unique to an individual pilot’s current level of experience and proficiency. They should be reevaluated periodically based upon experience and proficiency.

Single-Pilot Resource Management

Many of the concepts utilized in CRM have been successfully applied to single-pilot operations which led to the development of SRM. Defined as the art and science of managing all the resources (both on board the aircraft and from outside resources) available to a single pilot (prior to and during flight), SRM helps to ensure the successful outcome of the flight. As mentioned earlier, this includes risk management, situational awareness (SA), and CFIT awareness.

SRM training helps the pilot maintain SA by managing automation, associated control, and navigation tasks. This

enables the pilot to accurately assess hazards, manage resulting risk potential, and make good decisions.

To make informed decisions during flight operations, a pilot must be aware of the resources found both inside and outside the cockpit. Since useful tools and sources of information may not always be readily apparent, learning to recognize these resources is an essential part of SRM training. The pilot must not only identify the available resources, but he or she must also assess whether sufficient time is available to use a particular one, and the impact its use will have upon the safety of the flight.

If a pilot is flying alone into a confined area with no wind sock or access to a current wind report, should that pilot pick an approach path based on the direction of wind information received from an earlier weather brief? Making an approach into a confined area with a tailwind is a bad decision and can be avoided. Prior to landing, the pilot should use outside resources such as smoke, trees, and water on a pond to help him or her accurately determine which direction the winds are coming from. Pilots should never leave flying up to chance and hope for the best. Many accidents could and should be avoided by simply using the resources, internal and external that are available.

Internal resources are found in the cockpit during flight. Since some of the most valuable internal resources are ingenuity, knowledge, and skill, a pilot can expand cockpit resources immensely by improving these capabilities. This can be accomplished by frequently reviewing flight information publications, such as 14 CFR and the AIM, as well as by pursuing additional training.

No other internal resource is more important than the pilot’s own ability to control the situation, thereby controlling the aircraft. Helicopter pilots quickly learn that it is not possible to hover, single pilot, and pick up the checklist, a chart, or publication without endangering themselves, the aircraft, or those nearby.

Checklists are essential cockpit resources used to verify the aircraft instruments and systems are checked, set, and operating properly. They also ensure proper procedures are performed if there is a system malfunction or inflight emergency. Pilots at all levels of experience refer to checklists. The more advanced the aircraft is, the more crucial checklists are.

Therefore, have a plan on how to use the checklist (and other necessary publications) before you begin the flight. Always control the helicopter first. When hovering in an airport environment, the pilot can always land the aircraft to access

the checklist or a publication, or have a passenger assist with holding items. There is nothing more unsettling than being in flight and not having a well thought-out plan for managing the necessary documents and data. This lack of planning often leads to confusion, distractions and aircraft mishaps.

Another way to avoid a potentially complex and confusing situation is to remove yourself from the situation. The following is an example of how proper resource management and removal from a situation are vital to safe flight.

A single pilot is conducting a helicopter cross-country flight. He frequently goes to and is familiar with the final destination airport. Weather is briefed to be well above the minimum weather needed, but with isolated thunderstorms possible. For the pilot, this is a routine run-of-the-mill flight. He has done this many times before and has memorized the route, checkpoints, frequencies, fuel required and knows exactly what to expect.

However, once within 30 miles of the destination airport the pilot observes that weather is deteriorating, and a thunderstorm is nearby. The pilot assesses the situation and determines the best course of action is to reroute to another airport. The closest airport is an airport within Class C airspace. At this point, the pilot realizes the publications with the required alternate airport information are in the back of the helicopter out of reach. Now what?

The pilot continues toward the alternate airport while using the onboard equipment to access the information. He struggles to obtain the information because he or she is not thoroughly familiar with its operation. Finally, the information is acquired and the pilot dials in the appropriate alternate airfield information. Upon initial contact ARTCC (Air Route Traffic Control Center) notifies the pilot that he has entered the airspace without the required clearance; in effect the pilot has violated airspace regulations.

Things have gone from bad to worse for him. When did the trouble begin for this pilot and what options were available? Without a doubt, problems began during the planning phase, as the necessary resources were placed in the back of the aircraft, unavailable to the pilot during flight. Additional training with the available automated systems installed on the helicopter would have expedited access to the necessary information. What if they hadn't been installed or were inoperative?

Next, a poor decision to continue towards the Class C airspace was made. The pilot could have turned away from the Class C airspace, removing himself from the situation until the frequencies were entered and contact established. Remember, when possible, choose an option that gives more time to

determine a course of action. Proper resource management could have negated this airspace violation.

The example also demonstrates the need to have a thorough understanding of all the equipment and systems in the aircraft. As is often the case, the technology available today is seldom used to its maximum capability. It is necessary to become as familiar as possible with this equipment to utilize all resources fully. For example, advanced navigation and autopilot systems are valuable resources. However, if pilots do not fully understand how to use this equipment, or they rely on it so much they become complacent, the equipment can become a detriment to safe flight.

Another internal resource is the Rotorcraft Flight Manual (RFM). [Figure 13-4] The RFM:

- Must be on board the aircraft.
- Is indispensable for accurate flight planning.
- Plays a vital role in the resolution of inflight equipment malfunctions.

Other valuable flight deck resources include current aeronautical charts and publications, such as the Airport/Facility Directory (A/FD).

As stated previously, passengers can also be a valuable resource. Passengers can help watch for traffic and may be able to provide information in an irregular situation, especially if they are familiar with flying. Crew briefs to passengers should always include some basic helicopter terminology. For example, explain that in the event you ask them if you are clear to hover to the right, their response should be either “yes, you are clear to hover to the right” or “no you are not clear.” A simple yes or no answer can be ambiguous. A strange smell or sound may alert a passenger to a potential problem. As PIC, a pilot should brief passengers before the flight to make sure that they are comfortable voicing any concerns.

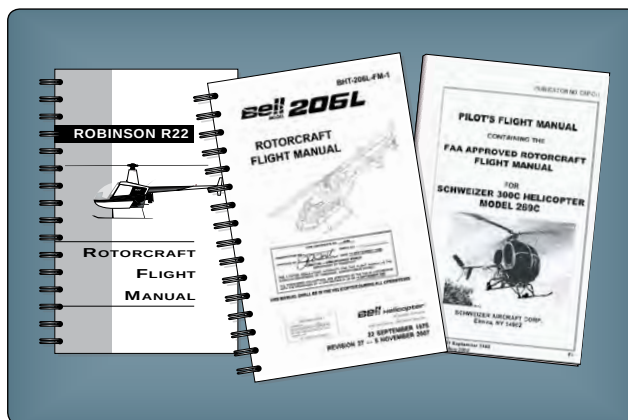


Figure 13-4. Rotorcraft Flying Manual (RFM).

Instruction that integrates Single-Pilot Resource Management into flight training teaches aspiring pilots how to be more aware of potential risks in flying, how to identify those risks clearly, and how to manage them successfully. The importance of integrating available resources and learning effective SRM skills cannot be overemphasized. Ignoring safety issues can have fatal results.

Risk Management

Risk management is a formalized way of dealing with hazards. It is the logical process of weighing the potential cost of risks from hazards against the possible benefits of allowing those risks from hazards to stand unmitigated. It is a decision-making process designed to identify hazards systematically, 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 preplanned, viable alternatives available in the event the original flight cannot be accomplished as planned.

Two defining elements of risk management are hazard and risk.

- 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. For example, binding in the antitorque pedals represents a hazard.
- Risk is the future impact of a hazard that is not

controlled or eliminated. It is the possibility of loss or injury. The level of risk is measured by the number of people or resources affected (exposure), the extent of possible loss (severity), and the likelihood of loss (probability).

A hazard can be a real or perceived condition, event, or circumstance that a pilot encounters. Learning how to identify hazards, assess the degree of risk they pose, and determine the best course of action is an important element of a safe flight.

Four Risk Elements

During each flight, decisions must be made regarding events that involve interactions between the four risk elements—the PIC, the aircraft, the environment, and the operation. The decision-making process involves an evaluation of each of these risk elements to achieve an accurate perception of the flight situation. [Figure 13-5]

One of the most important decisions that a PIC must make is the go/no-go decision. Evaluating each of these risk elements can help a pilot decide whether a flight should be conducted or continued. In the following situations, the four risk elements and how they affect decision-making are evaluated.

Pilot—A pilot must continually make decisions about personal competency, condition of health, mental and emotional state, level of fatigue, and many other variables. A situation to consider: a pilot is called early in the morning to make a long flight. With only a few hours of sleep and congestion that indicates the possible onset of a cold, is that pilot safe to fly?

Aircraft—A pilot frequently bases decisions to fly on

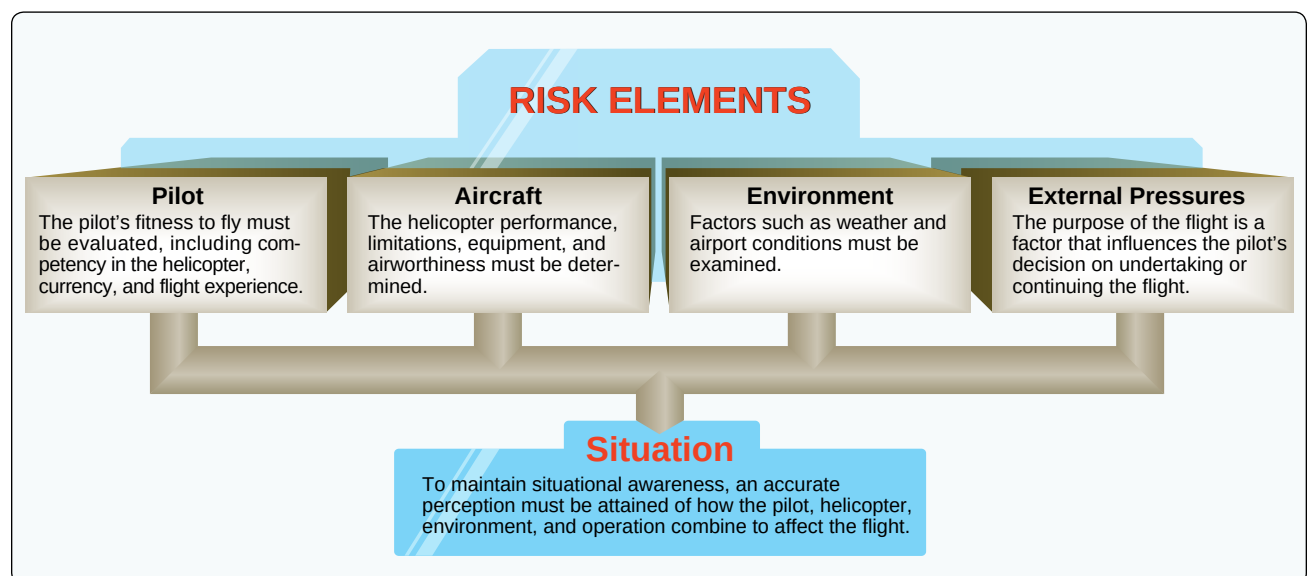


Figure 13-5. Risk elements to evaluate in decision-making.

personal evaluations of the aircraft, such as its powerplant, performance, equipment, fuel state, or airworthiness. A situation to consider: en route to an oil rig an hour's flight from shore, having just passed the shoreline, the pilot notices the oil temperature at the high end of the caution range. Should the pilot continue out to sea or return to the nearest suitable heliport/airport?

Environment—This encompasses many elements unrelated to the pilot or aircraft. It can include such factors as weather, ATC, navigational aids (NAVAID), terrain, takeoff and landing areas, and surrounding obstacles. Weather is one element that can change drastically over time and distance. A situation to consider: a pilot is ferrying a helicopter cross-country and encounters unexpected low clouds and rain in an area of rising terrain. Does the pilot try to stay under them and scud run, or turn around, stay in the clear, and obtain current weather information?

External Pressures—The interaction between the pilot, the aircraft, and the environment is greatly influenced by the purpose of each flight operation. A pilot must evaluate the three previous areas to decide on the desirability of undertaking or continuing the flight as planned. It is worth asking why the flight is being made, how critical it is to maintain the schedule, and if the trip is worth the risks. A situation to consider: a pilot is tasked to take some technicians into rugged mountains for a routine survey in marginal weather. Would it be preferable to wait for better conditions to ensure a safe flight? How would the priorities change if a pilot were tasked to search for cross-country skiers who had become lost in deep snow and radioed for help?

Assessing Risk

It is important for a pilot to learn how to assess risk. Before a pilot can begin to assess risk, he or she must first perceive the hazard and attendant risk(s). In aviation, experience, training, and education help a pilot learn how to spot hazards quickly and accurately. During flight training, the instructor should point out the hazards and attendant risks to help the student pilot learn to recognize them.

Once a hazard is identified, determining the probability and severity of an accident (level of risk associated with it) becomes the next step. For example, the hazard of binding in the antitorque pedals poses a risk only if the helicopter is flown. If the binding leads to a loss of directional control, the risk is high that it could cause catastrophic damage to the helicopter and the passengers. The pilot learns to identify hazards and how to deal with them when they are incorporated into the training program.

Every flight has hazards and some level of risk associated

with it. It is critical that pilots be able to:

- Differentiate, in advance, between a low-risk flight and a high-risk flight.
- Establish a review process and develop risk mitigation strategies to address flights throughout that range.

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

Individuals training to be helicopter pilots should remember that the helicopter accident rate is 30 percent higher than the accident rate for fixed-wing aircraft. While many factors contribute to this, students must recognize the small margin of error that exists for helicopter pilots in making critical decisions. In helicopters, certain emergency actions require immediate action by the pilot. In the event of an engine malfunction, failure to immediately lower the collective results in rotor decay and failed autorotation. Fixed wing pilots may have slightly more time to react and establish a controllable descent. According to the General Aviation (GA) Joint Steering Committee, the leading causes of accidents in GA are CFIT (see p.14-15), weather, runway incursions, pilot decision-making, and loss of control. These causes are referred to as pilot-error, or human factors related, accidents. CFIT, runway incursions, and loss of control type accidents typically occur when the pilot makes a series of bad judgments, which leads to these events. For example, when the pilot has not adequately planned the flight and the pilot subsequently fails to maintain adequate situational awareness to avoid the terrain, a CFIT accident occurs.

While the reasons for individual helicopter incidents vary, it can be argued that it is the helicopter's flight mode and operational complexity that directly contributes to each incident. By nature of its purpose, a helicopter usually flies closer to terrain than does a fixed-wing aircraft. Subsequently, minimal time exists to avoid CFIT, weather related, or loss of control type incidents that require quick and accurate assessments. Fixed-wing aircraft normally fly at higher altitudes and are flown from prepared surface to prepared surface. Helicopters are often operated in smaller, confined area-type environments and require continuous pilot control. Helicopter pilots must be aware of what rotor wash can do when landing to a dusty area or prior to starting where loose debris may come in contact with the rotor blades.

Often, the loss of control occurs when the pilot exceeds design or established operating standards, and the resulting situation exceeds pilot capability to handle it successfully. The FAA generally characterizes these occurrences as resulting from poor judgment. Likewise, most weather-related accidents are not a result of the weather per se, but of a failure of the pilot to avoid a weather phenomenon for which the aircraft is not equipped, or the pilot is not trained to handle. That is, the pilot decides to fly or to continue into conditions beyond pilot capability, an action commonly considered to be demonstrating bad judgment.

It cannot be emphasized enough that the helicopter's unique capabilities come with increased risk. Since most helicopter operations are conducted by a single pilot, the workload is increased greatly. Low-level maneuvering flight (a catch-all category for different types of flying close to terrain or obstacles, such as power line patrol, wildlife control, crop dusting, air taxiing, and maneuvering for landing after an instrument approach), is one of the largest single categories of fatal accidents.

Fatal accidents that occur during approach often happen at night or in instrument flight rules (IFR) conditions. Takeoff/initial climb accidents are frequently due to the pilot's lack of awareness of the effects of density altitude on aircraft performance or other improper takeoff planning that results in loss of control during or shortly after takeoff. One of the most lethal types of GA flying is attempting VFR flight into instrument meteorological conditions (IMC). Accidents involving poor weather decision-making account for about 4 percent of the total accidents but 14 percent of the fatal mishaps. While weather forecast information has been gradually improving, weather should remain a high priority for every pilot assessing risk.

Using the 3P Model to Form Good Safety Habits

As discussed in the Pilot's Handbook of Aeronautical Knowledge, the Perceive, Process, Perform (3P) model helps a pilot assess and manage risk effectively in the real world. [Figure 13-6]

To use this model, the pilot will:

- Perceive hazards
- Process level of risk
- Perform risk management

Let's put this to use through a common scenario, involving a common task, such as a confined area approach. As is often the case, the continuous loop consists of several elements; each element must be addressed through the 3P process.

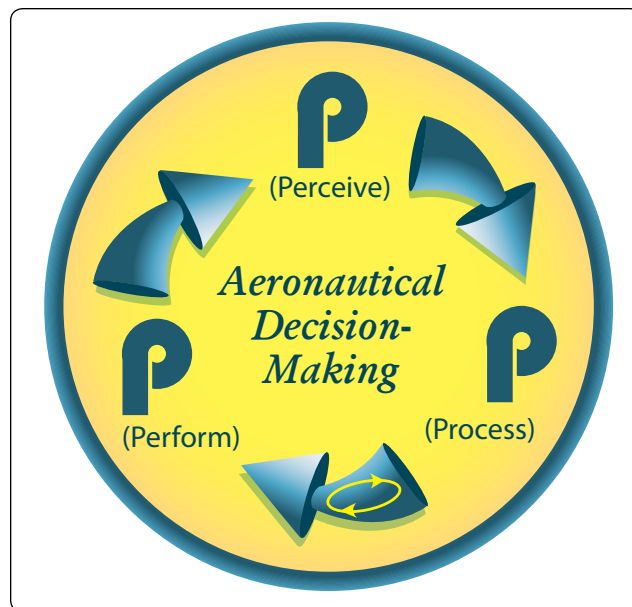


Figure 13-6. 3P Model.

A utility helicopter pilot receives the task of flying four passengers into a remote area for a hunting expedition. The passengers have picked the location where they would like to be dropped off based on the likelihood of wildlife being in the area. The area has steep, rugged terrain in a series of valleys and canyons leading up to large mountains.

Upon arrival at the location, the pilot locates a somewhat large confined area near the base of one of the mountains. The pilot begins the 3P process by quickly noting (or perceiving) the hazards that affect the approach, landing, and takeoff. Through thorough assessment the pilot takes into consideration:

- *Current aircraft weight/power available,*
- *Required approach angle to clear the trees for landing in the confined area,*
- *Wind direction and velocity,*
- *Limited approach and departure paths (due to constricting terrain),*
- *Escape routes should the approach need to be terminated prior to landing,*
- *Possible hazards, such as wires or structures either around the landing site or inside of the confined area, and*
- *The condition of the terrain at the landing site. Mud, dust, and snow can be extreme hazards if the pilot is not properly trained to land in those particular conditions.*

The pilot reviews the 3P process for each hazard. The pilot has perceived the risk associated for each of the bullets listed above. Now, the pilot assesses the risk level of each and what to do to manage or mitigate the risk.

The aircraft weight/power risk is assessed as low. While performing power checks, the pilot verified adequate out of ground effect (OGE) power exists. The pilot is also aware that, in this scenario, the departure DA (6,500 feet) is greater than the arrival location DA (6,000 feet) and that several hundred pounds of fuel have been burned off en route. Furthermore, once the passengers have disembarked, more power will be available for departure.

The pilot estimates that the highest obstacles along the approach path are 70–80 feet in height. With the size of the confined area, a normal approach angle can be maintained to clear these obstacles, giving this a low risk level. To further mitigate this risk the pilot has selected mental checkpoints along the approach path that will serve as go/no-go points should the pilot feel any assessed parameter is being exceeded.

Wind direction and velocity are assessed as a medium risk because (for this scenario) the direction of the wind is slightly offset from the chosen approach path, creating a 15–20° crosswind with a steady 10-knot wind. The pilot also takes into consideration that, due to the terrain, the wind direction and velocity may change during the approach. The pilot's experience and awareness of the complexity of mountain flow wind provide a management tool for risk reduction.

From an approach and departure standpoint, the risk is assessed to be medium. There is only one viable approach and departure path. Given the size of the confined area and the wind direction, the approach and departure path is deemed acceptable.

The pilot assigns a medium risk level to the selection of an escape route. The pilot is aware of the constricting terrain on either side. Although adequate area exists for maneuvering, the pilot realizes there are physical boundaries and that they can affect the options available should the pilot need to conduct a go-around or abort the approach. Again, the pilot uses mental checkpoints to ensure an early decision is made to conduct a go-around, if needed. The selected go-around or escape route will be in line with the selected approach/ departure path and generally into the wind.

As you may have noticed, one identified hazard and its correlating risk management action may have subsequent impact on other factors. This demonstrates the need for continuous assessment and evaluation of the impact of chosen courses of action.

The 3P model offers three good reasons for its use. First, it is fairly simple to remember. Second, it offers a structured, efficient, and systematic way to identify hazards, assess risk, and implement effective risk controls. Third, practicing risk management needs to be as automatic as basic aircraft control. As is true for other flying skills, risk management thinking habits are best developed through repetition and consistent adherence to specific procedures.

Once the pilot completes the 3P decision process and selects a course of action, the process begins anew as the set of circumstances brought about by the selected course of action requires new analysis. Thus, the decision-making process is a continuous loop of perceiving, processing, and performing.

Workload or Task Management

One component of SRM is workload or task management. Research shows that humans have a limited capacity for information. Once information flow exceeds the person's ability to mentally process the information, any additional information becomes unattended or displaces other tasks and information already being processed. Once this situation occurs, only two alternatives exist: shed the unimportant tasks or perform all tasks at a less than optimal level. Like an overloaded electrical circuit, either the consumption must be reduced or a circuit failure is experienced.

Effective workload management ensures essential operations are accomplished by planning and then placing them in a sequence that avoids work overload. As a pilot gains experience, he or she learns to recognize future workload requirements and can prepare for high workload periods during times of low workload.

Reviewing the appropriate chart and setting radio frequencies well in advance of need help reduce workload as a flight nears the airport. In addition, a pilot should listen to Automatic Terminal Information Service (ATIS), Automated Surface Observing System (ASOS), or Automated Weather Observing System (AWOS), if available, and then monitor the tower frequency or Common Traffic Advisory Frequency (CTAF) to get a good idea of what traffic conditions to expect. Checklists should be performed well in advance so there is time to focus on traffic and ATC instructions. These procedures are especially important prior to entering a high-density traffic area, such as Class B airspace.

To manage workload, items should be prioritized. For example, during any situation, and especially in an emergency, a pilot should remember the phrase “aviate, navigate, and communicate.” This means that the first

thing a pilot should do is make sure the helicopter is under control, then begin flying to an acceptable landing area. Only after the first two items are assured should a pilot try to communicate with anyone.

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

A very good example of this is inadvertent IMC. Once entering into bad weather, work overload can occur immediately. Mentally, the pilot must transition from flying outside of the aircraft to flying inside the aircraft. Losing all visual references can cause sensory overload and the ability to think rationally can be lost. Instead of trusting the aircraft's instruments, pilots may try to hang onto the few visual references that they have, and forget all about all other factors surrounding them. Instead of slowing the helicopter down they increase airspeed. This can be caused by an oculogravic illusion. This type of illusion occurs when an aircraft accelerates and decelerates. Inertia from linear accelerations and decelerations cause the otolith organ to sense a nose-high or nose-low attitude. Pilots falsely perceive that the aircraft is in a nose-high attitude. Therefore, pilots increase airspeed. Pilots can also be looking down for visual references and forget about the hazards in front of them. Finally, since the pilots are not looking at the flight instruments, the aircraft is not level. All of this can be avoided by proper training and proper planning. If going inadvertent IMC is your only course of action, pilots must commit to it and fly the helicopter using only the flight instruments and not trying to follow the few visual references they have.

When a work overload situation exists, a pilot needs to:

- Stop,
- Think,
- Slow down, and then
- Prioritize.

It is important for a pilot to understand how to decrease workload by:

- Placing a situation in the proper perspective,
- Remaining calm, and
- Thinking rationally.

These key elements reduce stress and increase the pilot's ability to fly safely. They depend upon the experience,

discipline, and training that each safe flight earns. It is important to understand options available to decrease workload. For example, setting a radio frequency may be delegated to another pilot or to a passenger, freeing the pilot to perform higher-priority tasks.

Situational Awareness

In addition to learning to make good aeronautical decisions, and learning to manage risk and flight workload, SA is an important element of ADM. SA is the accurate perception and understanding of all the factors and conditions within the four fundamental risk elements (PAVE) that affect safety before, during, and after the flight. SA involves being aware of what is happening around you, in order to understand how information, events, and your own actions will impact your goals and objectives, both now and in the near future. Lacking SA or having inadequate SA has been identified as one of the primary factors in accidents attributed to human error.

SA in a helicopter can be quickly lost. Understanding the significance and impact of each risk factor independently and cumulatively aid in safe flight operations. It is possible, and all too likely, that we forget flying while at work. Our occupation, or work, may be conducting long line operations, maneuvering around city obstacles to allow a film crew access to news events, spraying crops, ferrying passengers or picking up a patient to be flown to a hospital. In each case we are flying a helicopter. The moment we fail to account for the aircraft systems, the environment, other aircraft, hazards, and ourselves, we lose SA.

To maintain SA, all of the skills involved in SRM are used. For example, an accurate perception of pilot fitness can be achieved through self-assessment and recognition of hazardous attitudes. A clear assessment of the status of navigation equipment can be obtained through workload management, while establishing a productive relationship with ATC can be accomplished by effective resource use.

Obstacles to Maintaining Situational Awareness

What distractions interfere with our focus or train of thought? There are many. A few examples pertinent to aviation, and helicopters specifically, follow.

Fatigue, frequently associated with pilot error, is a threat to aviation safety because it impairs alertness and performance. *[Figure 13-7]* The term is used to describe a range of experiences from sleepy or tired to exhausted. Two major physiological phenomena create fatigue: circadian rhythm disruption and sleep loss.

Many helicopter jobs require scheduling flexibility, frequently affecting the body's circadian rhythm. You

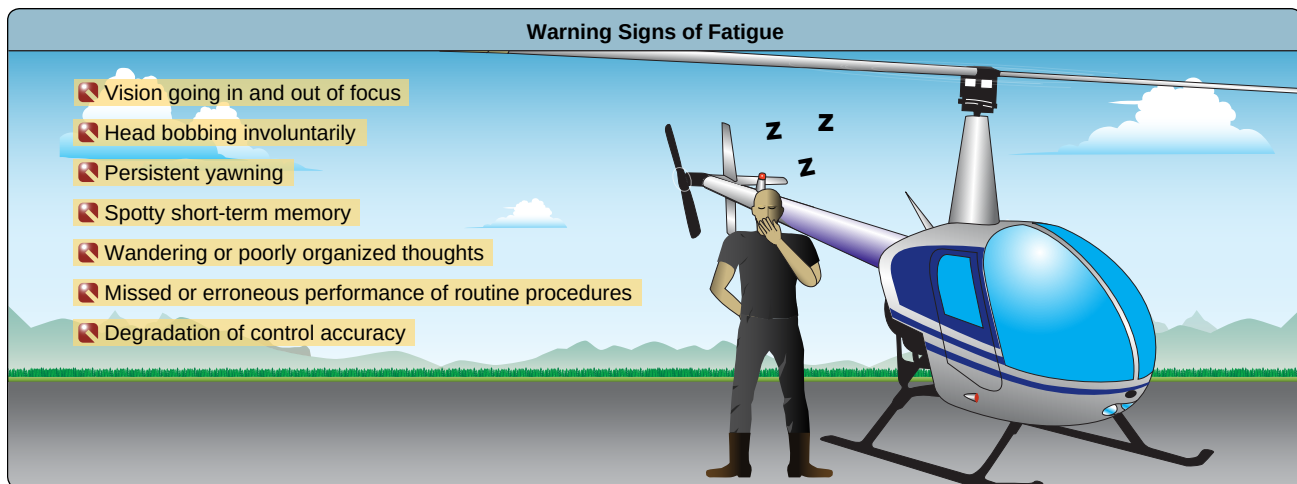


Figure 13-7. Warning signs of *fatigue* according to the FAA Civil Aerospace Medical Institute (CAMI).

may be flying a day flight Monday and then at night on Tuesday. Your awareness of how your body and mind react to this variation in schedule is vital to safety. This disruptive pattern may result in degradation of attention and concentration, impaired coordination, and decreased ability to communicate.

Physical fatigue results from sleep loss, exercise, or physical work. Factors such as stress and prolonged performance of cognitive work result in mental fatigue. Consecutive days of flying the maximum allowable flight time can fatigue a pilot, mentally and physically. It is important to take breaks within the workday, as well as days off when possible. When you find yourself in this situation, take an objective, honest assessment of your state of mind. If necessary, use rest periods to allow rejuvenation of the mind and body. [Figure 13-8]

Fatigue also occurs under circumstances in which there is anticipation of flight followed by inactivity. For instance, a pilot is given a task requiring a specific takeoff time. In anticipation of the flight, the pilot's adrenaline kicks in and SA is elevated. After a delay (weather, maintenance, or any other unforeseen delay), the pilot feels a letdown, in effect, becoming fatigued. Then, upon resuming the flight, the pilot does not have that same level of attention.

Complacency presents another obstacle to maintaining SA. Defined as overconfidence from repeated experience with a specific activity, complacency has been implicated as a contributing factor in numerous aviation accidents and incidents. When activities become routine, a pilot may have a tendency to relax and not put as much effort into performance. Like fatigue, complacency reduces a pilot's effectiveness on the flight deck. However, complacency is more difficult to recognize than fatigue, since everything seems to be progressing smoothly.

Since complacency seems to creep into our routine without notice, ask what has changed. The minor changes that go unnoticed can be associated with the four fundamental risks we previously discussed: pilot, aircraft, environment, and external pressures.

As a pilot, am I still using checklists or have I become reliant on memory to complete my checks? Do I check (Notices to Airmen) NOTAMs before every flight or only when I think it is necessary? And the aircraft: did I feel that vibration before or is it new? Was there a log book entry for it? If so,

Countermeasures

- Long naps (3–4 hours*) can restore alertness for 12–15 hours.
- Short power naps (10–30 minutes*) can restore alertness for 3–4 hours.
- Eat high-protein meals.
- Drink plenty of fluids, especially water.
- Rotate flight tasks and converse with other crew members or passengers.
- Keep the flight deck temperature cool.
- Move/stretch in the seat, and periodically get up to walk around the aircraft, if possible.

* Allow 15–20 minutes after awakening to become fully alert before assuming aircrew duties.

Figure 13-8. Countermeasures to fatigue according to the FAA Civil Aerospace Medical Institute (CAMI).

has it been checked?

Complacent acceptance of common weather patterns can have huge impacts on safety. The forecast was for clearing after the rain shower, but what was the dew-point spread? The winds are greater than forecast. Will this create reduced visibility in dusty, snowy areas or exceed wind limitations?

While conducting crop spraying, a new agent is used. Does that change the weight? Does that change the flight profile and, if so, what new hazards might be encountered? When things are going smoothly, it is time to heighten your awareness and become more attentive to your flight activities.

Advanced avionics have created a high degree of redundancy and dependability in modern aircraft systems, which can promote complacency and inattention. Routine flight operations may lead to a sense of complacency, which can threaten flight safety by reducing SA.

Loss of SA can be caused by a minor distraction that diverts the pilot's attention from monitoring the instruments or scanning outside the aircraft. For example, a gauge that is not reading correctly is a minor problem, but it can cause an accident if the pilot diverts attention to the perceived problem and neglects to control the aircraft properly.

Operational Pitfalls

There are numerous common behavioral traps that can ensnare the unwary pilot. Pilots, particularly those with considerable experience, try to complete a flight as planned, please passengers, and meet schedules. This basic drive to achieve can have an adverse effect on safety and can impose an unrealistic assessment of piloting skills under stressful conditions. These tendencies ultimately may bring about practices that are dangerous and sometimes illegal and may lead to a mishap. Pilots develop awareness and learn to avoid many of these operational pitfalls through effective SRM training. [Figure 13-9]

Controlled Flight Into Terrain (CFIT) Awareness

An emergency medical services (EMS) helicopter departed for a night flight to transport an 11-day-old infant patient from one hospital to another. No record was found indicating the pilot obtained a weather briefing before departure. The pilot had a choice of taking either a direct route that crossed a remote area of rugged mountainous terrain with maximum ground elevations of about 9,000 feet or a route that was about 10 minutes longer and followed an interstate highway with maximum ground elevations of about 6,000 feet. Radar data, which show about 4 minutes of the helicopter's flight before coverage was lost due to mountainous terrain, are

consistent with the flight following the direct route.

A search was initiated about 4 hours after the helicopter did not arrive at the destination hospital, and the wreckage was located the following morning. Physical evidence observed at the accident site indicated that the helicopter was in level flight at impact and was consistent with CFIT. [Figure 13-10]

CFIT is a type of accident that continues to be a major safety concern, while at the same time difficult to explain because it involves a pilot controlling an airworthy aircraft that is flown into terrain (water or obstacles) with inadequate pilot awareness of the impending disaster.

One constant in CFIT accidents is that outside visibility is limited, or the accident occurs at night and the terrain is not seen easily until just prior to impact. Another commonality among CFIT accidents is lack of SA. This includes not only horizontal awareness, and knowing where the helicopter is over the ground, but also vertical awareness.

Training, planning, and preparation are a pilot's best defenses for avoiding CFIT accidents. For example, take some time before takeoff to become familiar with the proposed flight and the terrain. Avoidance of CFIT begins before the helicopter departs the home location. Proper planning, including applied risk mitigation must occur before the aircraft is even started. Thorough assessment of terrain, visibility, pilot experience and available contingencies must be conducted. If necessary, delay or postpone the flight while on the ground. The decision to abort the flight is much easier to make in the planning room than in the air. In case conditions deteriorate once in flight. Have contingency options available.

While many CFIT accidents and incidents occur during nonprecision approaches and landings, great measures have been taken to improve instrument training, equipment and procedures. For the qualified pilot, instrument flight should not be avoided, but rather, trained as a viable option for safely recovering the aircraft. Like any other training, frequent instrument training builds confidence and reassurance.

Good instrument procedures include studying approach charts before leaving cruise altitude. Key fixes and airport elevation must be noted and associated with terrain and obstacles along the approach path. Pilots should have a good understanding of both approach and departure design criteria to understand fully the obstacle clearance margins built into them. Some pilots have the false belief that ATC provides obstacle clearance while en route off airways. The pilot is ultimately responsible for obstacle clearance.

Operational Pitfalls	
Peer Pressure	It would be foolish and unsafe for a new pilot to attempt to compete with an older, more experienced pilot. The only safe competition should be completing the most safe flights with no one endangered or hurt and the aircraft returned to service. Efficiency comes with experience and on-the-job training.
Mindset	A pilot should be taught to approach every day as something new.
Get-There-Itis	This disposition impairs pilot judgment through a fixation on the original goal or destination, combined with a disregard for any alternative course of action.
Duck-Under Syndrome	A pilot may be tempted to arrive at an airport by descending below minimums during an approach. There may be a belief that there is a built-in margin of error in every approach procedure, or the pilot may not want to admit that the landing cannot be completed and a missed approach must be initiated.
Scud Running	It is difficult for a pilot to estimate the distance from indistinct forms, such as clouds or fog formation.
Continuing Visual Flight Rules (VFR) Into Instrument Conditions	Spatial disorientation or collision with ground/obstacles may occur when a pilot continues VFR into instrument conditions. This can be even more dangerous if the pilot is not instrument rated or current.
Getting Behind the Aircraft	This pitfall can be caused by allowing events or the situation to control pilot actions. A constant state of surprise at what happens next may be exhibited when the pilot is "getting behind" the aircraft.
Loss of Positional or Situational Awareness	In extreme cases of a pilot getting behind the aircraft, a loss of positional or situational awareness may result. The pilot may not know the aircraft's geographical location, or may be unable to recognize deteriorating circumstances.
Operating Without Adequate Fuel Reserves	Pilots should use the last of the known fuel to make a safe landing. Bringing fuel to an aircraft is much less inconvenient than picking up the pieces of a crashed helicopter! Pilots should land prior to whenever their watch, fuel gauge, low-fuel warning system, or flight planning indicates fuel burnout. They should always be thinking of unforecast winds, richer-than-planned mixtures, unknown leaks, mis-servicing, and errors in planning. Newer pilots need to be wary of fuselage attitudes in low-fuel situations. Some helicopters can port air into the fuel system in low-fuel states, causing the engines to quit or surge.
Descent Below the Minimum En Route Altitude	The duck-under syndrome, as mentioned above, can also occur during the en route portion of an IFR flight.
Flying Outside the Envelope	The pilot must understand how to check the charts, understand the results, and fly accordingly.
Neglect of Flight Planning, Preflight Inspections, and Checklists	All pilots and operators must understand the complexity of the helicopter, the amazing number of parts, and why there are service times associated with certain parts. Pilots should understand material fatigue and maintenance requirements. Helicopters are unforgiving of disregarded maintenance requirements. Inspections and maintenance are in place for safety: something functioning improperly can be the first link in the error chain to an accident. In some cases, proper maintenance is a necessary condition for insurance coverage.

Figure 13-9. *Operational pitfalls.*

Altitude error is another common cause of CFIT. Cases of altitude error involve disorientation with respect to the NAVAID, improper transition on approach, selecting the wrong NAVAID, or just plain lack of horizontal SA. Today's modern aircraft have sophisticated flight directors, autopilots, autothrottles, and flight management systems. These devices make significant contributions to the overall safety of flight,

but they are only machines that follow instructions. They do whatever is asked of them, even if it is wrong. When commanded, they unerringly follow instructions—sometimes straight into the ground. The pilot must ensure that both vertical and horizontal modes are correct and engaged. Cross-check autopilots constantly.

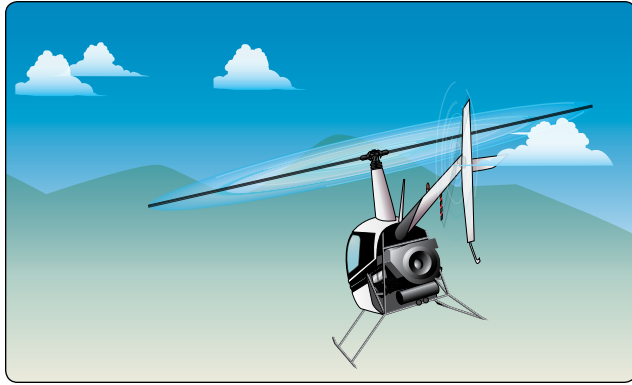


Figure 13-10. *Helicopter heading straight for mountain.*

When automated flight equipment is not available, great care must be taken to prepare properly for a night flight. SRM becomes more challenging under the cover of darkness, and caution should be exercised when determining what artificial light source to use inside the aircraft. A light source that is too bright will blind the pilot from seeing outside obstacles or rising terrain. Certain colored lenses bleach out symbols and markings on a map. Conduct this planning on the ground, in a dark room if necessary, before the actual flight.

Pilots must be even more conservative with their decision-making and planning when flying at night. Flying becomes more difficult due to the degradation of our sensory perception and the lack of outside references. Beginning with preflight, looking over the helicopter with a flashlight can cause pilots to miss even the smallest discrepancy that they would easily see during the day. For example, failing to remove one or all of the tie downs and attempting to take off would probably result in a dynamic rollover accident. Whenever possible, preflight inspection should always be conducted during the day or in a lighted hangar. Depth perception is less acute; therefore, hover height should be increased to avoid contact with obstacles and hover speed should be reduced. Weather conditions can be very deceptive and difficult to detect in flight under night conditions. On a low-illumination night, it is easy to fly into clouds without realizing it before it is too late to correct.

Due to the number of recent CFIT night accidents, the NTSB issued a safety alert in 2008 about avoiding night CFIT accidents. That alert included the following information:

- Terrain familiarization is critical to safe visual operations at night. Use sectional charts or other topographic references to ensure the helicopter will safely clear terrain and obstructions all along the route.
- When planning a nighttime VFR flight, follow IFR practices, such as climbing on a known safe course

until well above surrounding terrain. Choose a cruising altitude that provides terrain separation similar to IFR flights (2,000 feet above ground level in mountainous areas and 1,000 feet above the ground in other areas). Using this technique, known obstacles, such as towers, will be avoided.

- When receiving radar services, do not depend on ATC to warn of terrain hazards. Although controllers try to warn pilots if they notice a hazardous situation, they may not always recognize that a particular VFR aircraft is dangerously close to terrain.
- When ATC issues a heading with an instruction to “maintain VFR,” be aware that the heading may not provide adequate terrain clearance. If any doubt exists about your ability to avoid terrain and obstacles visually, advise ATC immediately and take action to reach a safe altitude.
- For improved night vision, the FAA recommends the use of supplemental oxygen for flights above 5,000 feet.
- Obtain as much information about areas in which you will be flying, and the routes to them, by utilizing hazard maps and satellite imagery.
- Before flying at night to unfamiliar remote areas or areas with hazardous terrain, try to arrange a day flight for familiarization.
- If a pilot flies at night, especially in remote or unlit areas, consider whether a global positioning system (GPS)-based terrain awareness unit would improve the safety of the flight.

Of particular note in the 2008 safety alert is a comment regarding oxygen use above 5,000 feet. Most helicopters are neither required nor equipped for supplemental oxygen use at this altitude. Due to the physiological effect on night vision of reduced available oxygen at higher elevations, care should be taken to exercise light discipline. Interior lighting should be lowered to the lowest possible levels but must allow adequate illumination of necessary systems and instruments. This, in turn, allows greater recognition of outside obstacles and terrain features.

Limited outside visibility is one constant in CFIT accidents. In the accident cited at the beginning of this section, it appears the pilot failed to obtain a weather briefing. If the pilot had obtained one, he would probably have learned of the cloud cover and light precipitation present along his planned route of flight. The limited outside visibility probably caused the CFIT accident, since no evidence was found of any pre-impact mechanical discrepancies with the helicopter’s airframe or systems that would have prevented

normal operation.

Automation Management

Automation management is the control and navigation of an aircraft by means of the automated systems installed in the aircraft. One of the most important concepts of automation management is simply knowing when to use it and when not to.

Ideally, a pilot first learns to perform practical test standard (PTS) maneuvers and procedures in the aircraft manually, or hand flying. After successfully demonstrating proficiency in the basic maneuvers, the pilot is then introduced to the available automation and/or the autopilot. Obviously, in some aircraft, not all automated systems may be disengaged for basic flight. The purpose of basic flight without automation is to ensure the pilot can hand fly the maneuver when necessary.

Advanced avionics offer multiple levels of automation, from strictly manual flight to highly automated flight. No one level of automation is appropriate for all flight situations, but to avoid potentially dangerous distractions when flying with advanced avionics, the pilot must know how to manage the course indicator, the navigation source, and the autopilot. It is important for a pilot to know the peculiarities of the particular automated system in use. This ensures the pilot knows what to expect, how to monitor for proper operation, and promptly take appropriate action if the system does not perform as expected.

At the most basic level, managing the autopilot means knowing at all times which modes are engaged and which modes are armed to engage. The pilot needs to verify that armed functions (e.g., navigation tracking or altitude capture) engage at the appropriate time. Automation management is a good place to practice the callout technique, especially after arming the system to make a change in course or altitude. Callouts are verbalizations of particular flight guidance automation mode changes. In an attempt to reduce the risk for mode confusion some operators have required flight crews to callout all flight guidance automation mode changes as a means of forcing pilots to monitor the Flight Mode Annunciator (FMA).

Chapter Summary

This chapter focused on aeronautical decision-making, which includes SRM training, risk management, workload or task management, SA, CFIT awareness, and automation management. Factors affecting a helicopter pilot's ability to make safe aeronautical decisions were also discussed. The importance of learning how to be aware of potential risks in flying, how to clearly identify those risks, and how to manage them successfully were also explored.

Glossary

Absolute altitude. The actual distance an object is above the ground.

Advancing blade. The blade moving in the same direction as the helicopter. In helicopters that have counterclockwise main rotor blade rotation as viewed from above, the advancing blade is in the right half of the rotor disk area during forward movement.

Agonic Line. An isogonic line along which there is no magnetic variation.

Air density. The density of the air in terms of mass per unit volume. Dense air has more molecules per unit volume than less dense air. The density of air decreases with altitude above the surface of the earth and with increasing temperature.

Aircraft pitch. The movement of the aircraft about its lateral, or pitch, axis. Movement of the cyclic forward or aft causes the nose of the helicopter to pitch up or down.

Aircraft roll. The movement of the aircraft about its longitudinal axis. Movement of the cyclic right or left causes the helicopter to tilt in that direction.

Airfoil. Any surface designed to obtain a useful reaction of lift, or negative lift, as it moves through the air.

Airworthiness Directive. When an unsafe condition exists with an aircraft, the FAA issues an Airworthiness Directive to notify concerned parties of the condition and to describe the appropriate corrective action.

Altimeter. An instrument that indicates flight altitude by sensing pressure changes and displaying altitude in feet or meters.

Angle of attack. The angle between the airfoil's chord line and the relative wind.

Antitorque pedal. The pedal used to control the pitch of the tail rotor or air diffuser in a NOTAR® system.

Antitorque rotor. See tail rotor.

Articulated rotor. A rotor system in which each of the blades is connected to the rotor hub in such a way that it is free to change its pitch angle, and move up and down and fore and aft in its plane of rotation.

Autopilot. Those units and components that furnish a means of automatically controlling the aircraft.

Autorotation. The condition of flight during which the main rotor is driven only by aerodynamic forces with no power from the engine.

Axis of rotation. The imaginary line about which the rotor rotates. It is represented by a line drawn through the center of, and perpendicular to, the tip-path plane.

Basic empty weight. The weight of the standard helicopter, operational equipment, unusable fuel, and full operating fluids, including full engine oil.

Blade coning. An upward sweep of rotor blades as a result of lift and centrifugal force.

Blade damper. A device attached to the drag hinge to restrain the fore and aft movement of the rotor blade.

Blade feather or feathering. The rotation of the blade around the spanwise (pitch change) axis.

Blade flap. The ability of the rotor blade to move in a vertical direction. Blades may flap independently or in unison.

Blade grip. The part of the hub assembly to which the rotor blades are attached, sometimes referred to as blade forks.

Blade lead or lag. The fore and aft movement of the blade in the plane of rotation. It is sometimes called "hunting" or "dragging."

Blade loading. The load imposed on rotor blades, determined by dividing the total weight of the helicopter by the combined area of all the rotor blades.

Blade root. The part of the blade that attaches to the blade grip.

Blade span. The length of a blade from its tip to its root.

Blade stall. The condition of the rotor blade when it is operating at an angle of attack greater than the maximum angle of lift.

Blade tip. The furthestmost part of the blade from the hub of the rotor.

Blade track. The relationship of the blade tips in the plane of rotation. Blades that are in track will move through the same plane of rotation.

Blade tracking. The mechanical procedure used to bring the blades of the rotor into a satisfactory relationship with each other under dynamic conditions so that all blades rotate on a common plane.

Blade twist. The variation in the angle of incidence of a blade between the root and the tip.

Blowback. The tendency of the rotor disk to tilt aft in transition to forward flight as a result of unequal airflow.

Calibrated airspeed (CAS). Indicated airspeed of an aircraft, corrected for installation and instrumentation errors.

Center of gravity. The theoretical point where the entire weight of the helicopter is considered to be concentrated.

Center of pressure. The point where the resultant of all the aerodynamic forces acting on an airfoil intersects the chord.

Centrifugal force. The apparent force that an object moving along a circular path exerts on the body constraining the object and that acts outwardly away from the center of rotation.

Centripetal force. The force that attracts a body toward its axis of rotation. It is opposite centrifugal force.

Chip detector. A warning device that alerts you to any abnormal wear in a transmission or engine. It consists of a magnetic plug located within the transmission. The magnet attracts any metal particles that have come loose from the bearings or other transmission parts. Most chip detectors have warning lights located on the instrument panel that illuminate when metal particles are picked up.

Chord. An imaginary straight line between the leading and trailing edges of an airfoil section.

Chordwise axis. For semirigid rotors, a term used to describe the flapping or teetering axis of the rotor.

Coaxial rotor. A rotor system utilizing two rotors turning in opposite directions on the same centerline. This system is used to eliminate the need for a tail rotor.

Collective pitch control. The control for changing the pitch of all the rotor blades in the main rotor system equally and simultaneously and, consequently, the amount of lift or thrust being generated.

Coning. See blade coning.

Coriolis effect. The tendency of a rotor blade to increase or decrease its velocity in its plane of rotation when the center of mass moves closer to or farther from the axis of rotation.

Cyclic feathering. The mechanical change of the angle of incidence, or pitch, of individual rotor blades, independent of other blades in the system.

Cyclic pitch control. The control for changing the pitch of each rotor blade individually as it rotates through one cycle to govern the tilt of the rotor disk and, consequently, the direction and velocity of horizontal movement.

Degraded Visual Environment (DVE). Any flight environment of reduced visibility in which situational awareness of the aircrew or control of the aircraft may be severely diminished, completely lost, or may not be maintained as comprehensively as they are during flight operations within clear or undiminished visibility. DVE conditions are further categorized into eleven different types: smoke, smog, clouds, rain, fog, snow, whiteout, night, flat light, sand, and brownout.

Delta hinge. A flapping hinge with an axis skewed so that the flapping motion introduces a component of feathering that would result in a restoring force in the flap-wise direction.

Density altitude. Pressure altitude corrected for nonstandard temperature variations.

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

Direct control. The ability to maneuver a helicopter by tilting the rotor disk and changing the pitch of the rotor blades.

Direct shaft turbine. A single-shaft turbine engine in which the compressor and power section are mounted on a common driveshaft.

Disk area. The area swept by the blades of the rotor. It is a circle with its center at the hub and has a radius of one blade length.

Disk loading. The total helicopter weight divided by the rotor disk area.

Dissymmetry of lift. The unequal lift across the rotor disk resulting from the difference in the velocity of air over the advancing blade half and the velocity of air over the retreating blade half of the rotor disk area.

Drag. An aerodynamic force on a body acting parallel and opposite to relative wind.

Dual rotor. A rotor system utilizing two main rotors.

Dynamic rollover. The tendency of a helicopter to continue rolling when the critical angle is exceeded, if one gear is on the ground, and the helicopter is pivoting around that point.

Emergency Position Indicator Radio Beacon (ERIPB). A device used to alert search and rescue services in the event of an emergency by transmitting a coded message on the 406 MHz distress frequency, which is relayed by the Cospas-Sarsat global satellite system.

Feathering. The action that changes the pitch angle of the rotor blades by rotating them around their feathering (spanwise) axis.

Feathering axis. The axis about which the pitch angle of a rotor blade is varied. Sometimes referred to as the spanwise axis.

Feedback. The transmittal of forces, which are initiated by aerodynamic action on rotor blades, to the cockpit controls.

Flapping. The vertical movement of a blade about a flapping hinge.

Flapping hinge. The hinge that permits the rotor blade to flap and thus balance the lift generated by the advancing and retreating blades.

Flare. A maneuver accomplished prior to landing to slow a helicopter.

Free turbine. A turboshaft engine with no physical connection between the compressor and power output shaft.

Freewheeling unit. A component of the transmission or power train that automatically disconnects the main rotor from the engine when the engine stops or slows below the equivalent rotor rpm.

Fully articulated rotor system. See articulated rotor system.

Gravity. See weight.

Gross weight. The sum of the basic empty weight and useful load.

Ground effect. A usually beneficial influence on helicopter performance that occurs while flying close to the ground. It results from a reduction in upwash, downwash, and blade tip vortices, which provide a corresponding decrease in induced drag.

Ground resonance. Self-excited vibration occurring whenever the frequency of oscillation of the blades about the lead-lag axis of an articulated rotor becomes the same as the natural frequency of the fuselage.

Gyroscopic precession. An inherent quality of rotating bodies, which causes an applied force to be manifested 90° in the direction of rotation from the point where the force is applied.

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

Hunting. Movement of a blade with respect to the other blades in the plane of rotation, sometimes called leading or lagging.

In ground effect (IGE) hover. Hovering close to the surface (usually less than one rotor diameter distance above the surface) under the influence of ground effect.

Induced drag. That part of the total drag that is created by the production of lift.

Induced flow. The component of air flowing vertically through the rotor system resulting from the production of lift.

Inertia. The property of matter by which it will remain at rest or in a state of uniform motion in the same direction unless acted upon by some external force.

Isogonic line. Lines on charts that connect points of equal magnetic variation.

Knot. A unit of speed equal to one nautical mile per hour.

$L_{D_{MAX}}$. The maximum ratio between total lift (L) and total drag (D). This point provides the best glide speed. Any deviation from the best glide speed increases drag and reduces the distance you can glide.

Lateral vibration. A vibration in which the movement is in a lateral direction, such as imbalance of the main rotor.

Lead and lag. The fore (lead) and aft (lag) movement of the rotor blade in the plane of rotation.

Licensed empty weight. Basic empty weight not including full engine oil, just undrainable oil.

Lift. One of the four main forces acting on a helicopter. It acts perpendicular to the relative wind.

Load factor. The ratio of a specified load weight to the total weight of the aircraft.

Married needles. A term used when two hands of an instrument are superimposed over each other, as on the engine/rotor tachometer.

Mast. The component that supports the main rotor.

Mast bumping. Action of the rotor head striking the mast, occurring on underslung rotors only.

Navigational aid (NAVAID). Any visual or electronic device, airborne or on the surface, that provides point-to-point guidance information, or position data, to aircraft in flight.

Night. The time between the end of evening civil twilight and the beginning of morning civil twilight, as published in the American Air Almanac.

Normally aspirated engine. An engine that does not compensate for decreases in atmospheric pressure through turbocharging or other means.

One-to-one vibration. A low frequency vibration having one beat per revolution of the rotor. This vibration can be either lateral, vertical, or horizontal.

Out of ground effect (OGE) hover. Hovering a distance greater than one disk diameter above the surface. Because induced drag is greater while hovering out of ground effect, it takes more power to achieve a hover out of ground effect.

Parasite drag. The part of total drag created by the form or shape of helicopter parts.

Payload. The term used for the combined weight of passengers, baggage, and cargo.

Pendular action. The lateral or longitudinal oscillation of the fuselage due to its suspension from the rotor system.

Pitch angle. The angle between the chord line of the rotor blade and the reference plane of the main rotor hub or the rotor plane of rotation.

Pressure altitude. The height above the standard pressure level of 29.92 "Hg. It is obtained by setting 29.92 in the barometric pressure window and reading the altimeter.

Profile drag. Drag incurred from frictional or parasitic resistance of the blades passing through the air. It does not change significantly with the angle of attack of the airfoil section, but it increases moderately as airspeed increases.

Resultant relative wind. Airflow from rotation that is modified by induced flow.

Retreating blade. Any blade, located in a semicircular part of the rotor disk, in which the blade direction is opposite to the direction of flight.

Retreating blade stall. A stall that begins at or near the tip of a blade in a helicopter because of the high angles of attack required to compensate for dissymmetry of lift.

Rigid rotor. A rotor system permitting blades to feather, but not flap or hunt.

Rotational velocity. The component of relative wind produced by the rotation of the rotor blades.

Rotor. A complete system of rotating airfoils creating lift for a helicopter.

Rotor brake. A device used to stop the rotor blades during shutdown.

Rotor disk area. See disk area.

Rotor force. The force produced by the rotor, comprised of rotor lift and rotor drag.

Semirigid rotor. A rotor system in which the blades are fixed to the hub, but are free to flap and feather.

Shaft turbine. A turbine engine used to drive an output shaft, commonly used in helicopters.

Skid. A flight condition in which the rate of turn is too great for the angle of bank.

Skid shoes. Plates attached to the bottom of skid landing gear, protecting the skid.

Slip. A flight condition in which the rate of turn is too slow for the angle of bank.

Solidity ratio. The ratio of the total rotor blade area to total rotor disk area.

Span. The dimension of a rotor blade or airfoil from root to tip.

Split needles. A term used to describe the position of the two needles on the engine/rotor tachometer when the two needles are not superimposed.

Standard atmosphere. A hypothetical atmosphere based on averages in which the surface temperature is 59 °F (15 °C), the surface pressure is 29.92 "Hg (1013.2 Mb) at sea level, and the temperature lapse rate is approximately 3.5 °F (2 °C) per 1,000 feet.

Static stop. A device used to limit the blade flap, or rotor flap, at low rpm or when the rotor is stopped.

Steady-state flight. The type of flight experienced when a helicopter is in straight-and-level, unaccelerated flight, and all forces are in balance.

Symmetrical airfoil. An airfoil having the same shape on the top and bottom.

Tail rotor. A rotor turning in a plane perpendicular to that of the main rotor and parallel to the longitudinal axis of the fuselage. It is used to control the torque of the main rotor and to provide movement about the yaw axis of the helicopter.

Teetering hinge. A hinge that permits the rotor blades of a semirigid rotor system to flap as a unit.

Thrust. The force developed by the rotor blades acting parallel to the relative wind and opposing the forces of drag and weight.

Tip-path plane. The imaginary circular plane outlined by the rotor blade tips as they make a cycle of rotation.

Torque. In helicopters with a single, main rotor system, the tendency of the helicopter to turn in the opposite direction of the main rotor rotation.

Trailing edge. The rearmost edge of an airfoil.

Translating tendency. The tendency of the single-rotor helicopter to move laterally during hovering flight. Also called tail rotor drift.

Translational lift. The additional lift obtained when entering forward flight, due to the increased efficiency of the rotor system.

Transverse-flow effect. The condition of increased drag and decreased lift in the aft portion of the rotor disk caused by the air having a greater induced velocity and angle in the aft portion of the disk.

True altitude. The actual height of an object above mean sea level.

Turboshaft engine. A turbine engine transmitting power through a shaft as would be found in a turbine helicopter.

Twist grip. The power control on the end of the collective control.

Underslung. A rotor hub that rotates below the top of the mast, as on semirigid rotor systems.

Unloaded rotor. The state of a rotor when rotor force has been removed, or when the rotor is operating under a low or negative G condition.

Useful load. The difference between the gross weight and the basic empty weight. It includes the flight crew, usable fuel, drainable oil, if applicable, and payload.

Variation. The angular difference between true north and magnetic north; indicated on charts by isogonic lines.

Vertical vibration. A vibration in which the movement is up and down, or vertical, as in an out-of-track condition.

Vortex ring state. A transient condition of downward flight (descending through air after just previously being accelerated downward by the rotor) during which an appreciable portion of the main rotor system is being forced to operate at angles of attack above maximum. Blade stall starts near the hub and progresses outward as the rate of descent increases.

Weight. One of the four main forces acting on a helicopter. Equivalent to the actual weight of the helicopter. It acts downward toward the center of the earth.

Yaw. The movement of a helicopter about its vertical axis.

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