DEPARTMENT OF FLYING SAFETY
UNITED STATES ARMY PRIMARY HELICOPTER CENTER
FORT WOLTERS, TEXAS

File No. 1-403-2

STUDENT HANDOUT

HELICOPTER ACCIDENT PREVENTION

"HOW TO CRASH A HELICOPTER"

This paper will concern itself with some generalized recommendations on how to crash a helicopter. It will not deal extensively with forced landings to a relatively clear area where the pilot can be expected to make a safe autorotative touchdown. Rather, recommendations are made with respect to a forced landing situation where a crash landing is unavoidable, and the primary consideration is crew survival.

Rotary Wing Crash Dynamics

Where the fixed wing aircraft's dispensable structure is especially suited to arrest forward motion, the helicopter's dispensable structure (landing gear, lower fuselage, tail boom, and main rotor) can be used mainly to alleviate vertical impact. Consequently, the helicopter pilot has to be very cautious about forward velocity during excessively hard vertical impacts on soft terrain, or during a running landing between obstacles. The general rule for helicopters in this respect is: The worse the terrain, the more important it is to reduce the forward velocity of touchdown. Since a zero groundspeed touchdown requires more finesse, it would be unwise to use this technique when terrain permits a running touchdown.

What are the peak G-levels in a typical accident situation? A zero-groundspeed autorotation in a low silhoutte helicopter, touching down on hard-packed terrain at a sink rate of 1500 feet/minute, would expose the occupants to a vertical load of about 24-40 G's*. Spinal injuries are likely to occur under these circumstances but survival would not be at stake. The cockpit/cabin area would still be relatively intact--although distorted--but the aircraft would probably not be economically repairable. If the same landing on hard terrain were made with forward groundspeed, a peak horizontal declaration in the order of 15 to 25 G's would coincide with the peak vertical deceleration due to the increased frictional force while the vertical speed is being dissipated. A similar touchdown with forward velocity on soft terrain would probably be disastrous; the extremely high drag on the aircraft's bottom structure coupled with the forward inertia of the heavy components (transmission, engine, etc.) would tend to destroy the overall cockpit/cabin integrity. To avoid undue concern, it might be well to note that a 1500 foot/minute touchdown at zero groundspeed on soft terrain that allows one foot of additional vertical stopping distance would not have injurious effects.

The most important vertical impact attenuator is the main rotor, especially in low-silhouette helicopters such as the UH-1, where there is not enough structure under the occupiable area to cushion an excessive rate of sink. The ideal way to use the main rotor for this purpose is to make a zero-groundspeed tree landing; this causes the main rotor to act as an "umbrella" while the fuselage settles into the trees and loses its excess vertical velocity. (This technique is explained under the heading, "Touchdown".)

*Based on an effective stopping distance of about 4 inches.

Before getting into more detail in this area, it will be assumed that a complete engine failure or partial engine failure condition will precipitate this type emergency action. By way of review, the main symptoms of either a partial power loss or a complete engine failure are: (1) A sudden reduction in engine noise; (2) A sudden drop in engine and rotor RPM; (3) A left yaw resulting from the reduction in engine torque; (4) The partial or total lack of response to throttle movements. When a loss of engine power is detected, it is necessary to decrease collective pitch and apply right anti-torque pedal immediately in order to avoid a reduction in rotor RPM and to maintain a constant heading. Under partial power conditions the engine may operate relatively smoothly at reduced power or it may operate roughly or erratically with intermitent surges of power. In some instances where power loss is experienced with accompanying engine roughness or surging, the helicopter may sometimes be flown in a gradual descent at reduced power to a favorable landing area. However, under these conditions, the pilot should always be prepared for a complete power failure and an immediate autorotative landing. In the event that a power condition is accompanied by engine roughness, erratic operation, or power surging, immediate action should be taken to execute a "joined-needles" autorotation and land at the best and nearest area, using available power.

SETTING THE SCENE

From the pilot's point of view, there are two types of emergency landings:

a. Forced landing: When further flight is impossible, but not as a result of catastrophic aircraft control problems.

b. Precautionary landing: When further flight is possible, but inadvisable under certain conditions such as deteriorating weather, being lost, fuel shortage, and gradually developing engine trouble.

A precautionary landing, normally, is less hazardous than a forced landing because the pilot has more time for terrain selection, is subject to less stress, and can use power to compensate for errors in judgment or technique. Unfortunately, too many situations calling for precautionary landings are procrastinated into immediate forced landings because the pilot uses wishful thinking instead of reason, especially when dealing with a self-inflicted predicament. On the other hand, experience proves that an emergency situation that demands a quick, instinctive reaction without time for rationalization is often handled better than a situation that leaves time for "meditation" and "self-pity."

If serious injuries do not occur in emergency landings, they generally result from lack of understanding of the basic mechanics involved, compounded by one or more of the following factors:

a. Reluctance to accept the emergency situation. The pilot who won't face the fact that his aircraft will be on the ground in a very short time regardless of what he thinks or hopes is already handicapping himself. In his efforts to delay this dreaded moment, he tends to maintain his altitude at the expense of aircraft controllability. (Loss of speed and/or rotor RPM.)

b. The desire to save the aircraft, even when it implies a course of action that leaves no margin for error. If all goes well, the aircraft may sustain little or no damage; if the pilot loses his gamble, the aircraft as well as the occupants may be lost. Stretched glides and failure to allow for obstacles in the approach path are typical under these conditions.

c. Undue concern about getting hurt in a landing or rough terrain and its adverse effect on the pilot's judgment and technique.

To supplant all unnecessary apprehension by a justified dose of self-confidence, it might be best to introduce the chapters on actual landing techniques with the following statement:

> A helicopter pilot who understands and uses the guidelines presented in this pamphlet is not going to expose himself or his passengers to fatal injury during emergency landings under the most adverse conditions.

Before going further, we will touch on some basic considerations pertaining to our subject. In an emergency situation, the pilot will immediately be concerned with a quick survey of available terrain within autorotative glide distance of the helicopter. He should make an attempt to head toward the best terrain available and maneuver the helicopter according to existing wind conditions. These axioms are worthy of note: <u>A hard but controlled touchdown on bad terrain is often preferable to the stretching of an approach and running the risk of an uncontrolled touchdown on good terrain</u>. The pilot should <u>control</u> the crash as much as possible.

TERRAIN SELECTION

Except for the few critical seconds following takeoff, a pilot never has an excuse denying himself some form of choice in the selection of an emergency landing site. This does not mean that he has to fly around preoccupied with engine failure and suitable landing spots, but rather, that he has to develop some protective instincts and sound habits in the following areas:

a. Routing: Using imagination in the planning of a route goes a long way towards improving the survival aspects of a forced landing. The difference between a direct route which leaves no choice in case of an emergency and one that detours over "friendly" terrain is often a matter of only a few minutes or a few gallons of gas. The same type of defensive thinking should go into the selection of terrain over which local training flights are conducted and the direction of take-off from confined areas.

b. Altitude and Airspeed: More altitude above terrain means more choice, time-wise and distance-wise. Excess airspeed can be converted into altitude and therefore, into terrain choice. Flying needlessly low and slow over neck-breaking terrain is one of aviation's capital offenses. However, excessive altitude is not a blessing when it leads to indecision. The helicopter pilot should probably learn to think in terms of optimum altitude: high enough to make an autorotation and low enough to get the aircraft safely and quickly on the ground in case of a critical malfunction.

It is unfortunate that in most training situations so much stress is placed on the selection of a field that actually allows a (simulated) forced landing without damage. This training practice and the bias it creates put heavy demands on the composure of a pilot who finds himself beyond gliding distance of a suitable field. What is he expected to do? Call his instructor for further guidance or a refund? Obviously, no flight training is complete unless the student has been conditioned to accept the inevitability of aircraft damage when circumstances force him to sacrifice dispensable structure to protect the cockpit/cabin area.

Assuming that the pilot is beyond reach of suitable landing area, he should judge the terrain within gliding distance for its energy-absorbing capability. If sufficient altitude is available, he should head towards the area that seems to offer the best choice without being immediately concerned about a specific spot. When the available time is very short, the choice may be limited to a variety of obstacles, but it is still a choice as long as the pilot maintains control of the aircraft.

The following discussion of the pros and cons of the different types of terrain is intended as general orientation only:

a. Trees (Forest)

Accident experience proves conclusively that in an emergency situation trees can be a helicopter pilot's best friend. In conjunction with the modern, all-metal, main rotor blade, trees have an energy-absorbing capability that may even compensate for partial loss of aircraft control or an excessive sink rate. In practical terms this means that under certain circumstances (e.g., low rotor RPM or control difficulties) a tree landing may be less hazardous than one on flat, open terrain.

b. Water

It is difficult to explain the apparent reluctance of some pilots to ditch their helicopter in case of emergency. It may be the subconscious knowledge that the aircraft will most likely be a total loss, or fear of getting trapped. Based on actual experience, the ditching of a helicopter definitely presents much less of a problem, impact-wise, than a landing on very rough terrain or in high trees. If there are any problems they are mainly self-imposed ones in the form of premature evacuation of the occupants (before the main rotor has stopped) and failure to have all doors open at the time of water entry. The subject of ditching is covered separately in the last chapter of this pamphlet.

c. Desert

Selecting a suitable landing area in the desert should not present a problem. The survival and comfort aspects after landing, such as the proximity of settlements and the availability of water, food and shelter are sometimes more critical. For this reason, the original choice--when considerable altitude is available--should be one of direction rather than a specific spot. Since orientation is easily lost in the desert, it is advisable to make a mental note of a walk-out direction in relation to certain terrain features or the planned landing direction. This suggestion is made without inferring that a conspicuously located aircraft should be left in favor of an uncertain search for comfort.

d. Mountains

It is impossible to give general rules for terrain selection in mountainous terrain. What was said earlier about "giving yourself a chance" in case of an emergency definitely applies to the pilot's initiative and habits in mountain flying. The pilot should learn to instinctively avoid situations where an emergency would leave him without choice. Once he develops this instinct, the helicopter pilot will discover that the unique flying characteristics of his aircraft give him considerably more freedom from worry in rugged terrain than his fixed wing colleague.

APPROACH

Terrain selection from altitude is initially based on appearances, and therefore, not always final. As the actual terrain features become more apparent, the pilot should not hesitate to discard his original choice for one that is obviously better, but as a general rule, he should not change his mind more than once. A well planned and executed crash landing can be less hazardous than a wild approach into a large established field. Once the pilot has made his final decision he should suppress the tendency to keep looking for other--and hopefully better--fields and concentrate on the approach. The best advice here is to fly a normal landing pattern, without aggravating an already difficult situation by using non-standard or unproven procedures.

When the pilot has time to maneuver, the direction of the approach is governed by two factors: the wind and the location of obstacles in the approach path. A third factor--the dimensions of the chosen field--enters the picture only when ample landing space is available. A simple rule of thumb in the latter case is: When the wind velocity is ten percent of the touchdown speed, a downwind landing requires fifty percent more ground roll--or sliding distance--than a landing into the wind.

A critical situation is one where the only available field is a confined area that will accommodate the aircraft only when the pilot executes a flawless approach. From the pilot's point of view, this set-up is a perfect trap which he can avoid only by asking himself: From what direction should I approach to avoid disastrous results from possible obvious approach errors (coming in too high or too low) it is apparent that obstacles (wires, buildings, trees, etc.) permit only one type of error: coming in too high. To encourage the hard-to-convince pilot to treat obstacles with respect, the probable results of coming in too low are listed:

a. Striking an obstacle during the final part of the approach almost always implies loss of aircraft control before the planned touchdown point is reached.

b. Stretching the glide across obstacles to reach an open area means sacrificing rotor RPM and yielding control over the rate of sink at touchdown.

The foregoing should make it clear that the approach direction into a confined area within gliding range is determined by obstacles as well as wind. To reiterate: The pilot should aim at a wind/obstacle combination that permits a controlled touchdown with the greatest margin of error. When there are no obstacles to contend with, wind should be an overriding factor only:

a. When its effect is readily apparent in the aircraft's ground track.

b. When there is sufficient time to do the necessary maneuvering without jeopardizing aircraft controllability.

Too many approaches go sour and end as serious mishaps because the crew pays too much attention to the fixing of whatever they thought went wrong (engine restarting attempts, etc.) and not enough to the planning and execution of the approach. Emergency landing procedures and aircraft control always take precedence over restart procedures, even if the pilot knows--which is the exception rather than the rule--that the situation is correctable within the available time. There is no need to explain that pre-planned crew coordination for occasions like this can save the day.

In case of an erratically operating engine, it is often better to kill the engine--and shut-off the fuel--before final approach. This action not only preserves the pilot's initiative but it reduces or eliminates the most common fire hazard: a hot engine. (A turbine engine cools off extremely fast after flameout.) Another ignition source--the electrical system--should be handled in a similar manner when the pilot is no longer in need of the system's services and when time permits.

Advice concerning protective equipment should not be necessary since every helicopter pilot always has his seat belt, shoulder harness, and helmet chin strap fastened. Contrary to what most handbooks recom--mend, the locking of the shoulder harness (reel) is optional; it should be done only if time permits and if the pilot can do it without endangering aircraft control. The purpose of the automatic reel is to give the pilot the required freedom of movement in the cockpit while at the same time automatically protecting him in case of an abrupt deceleration (in excess of 2 to 3 G's.) To obtain real benefit from the manual locking of the shoulder harness, all slack should be taken out of the straps after moving the control handle from automatic to manual.

TOUCHDOWN

Towards the end of the approach, the pilot is in the best position to judge his aircraft's remaining maneuvering capability with respect to the rapidly narrowing down terrain choice. He must now make the final decision about the exact touchdown spot and the manner of touchdown. This is not the time to get alarmed or revert to the supernatural because the terrain doesn't look as good as it did from altitude, or because the best area is overshot or undershot. Of all the errors that can be made up to this time, there is only one that's critical: loss of rotor RPM and the resulting loss of control over the manner of touchdown.

The following discussion of touchdown techniques deals with landings on open terrain and tree landings.

a. Open Terrain

Before instinctively heading towards open terrain (including established fields) the pilot should ask himself the following questions:

(1) Can I reach the open area with a normal glide without being tempted to stretch it? (Note: The speed for maximum glide distance, power-off, is not necessarily the same as the speed for minimum rate of descent.)

(2) Does the surface permit a running landing in case of an

excessively hard touchdown?

(3) If I decide on a running landing, do I have sufficient aircraft control to insure a touchdown without drifting or crabbing?

(4) If the surface conditions are poor, do density altitude and gross load permit a zero groundspeed touchdown at a reasonable sink rate or do I have to compromise in the form of a minimum ground roll touchdown?

As explained earlier, a running landing is less demanding with respect to pilot judgment and technique than a zero groundspeed touchdown. It may even be said that a straightforward emergency, such as an engine failure, over terrain that permits a running landing hardly presents a problem. However, the pilot has to be prepared for the most adverse conditions and for this reason his training cannot be considered complete unless he has been taught to perform a zero groundspeed autorotative touchdown.

b. Tree Landings

When a tree landing is unavoidable or preferable, the pilot should select a touchdown spot based on the following considerations:

(1) The height of a tree is less critical than the height above the ground where it begins to branch. Tall trees with thin tops allow too much free-fall height after the aircraft passes through the branches.

(2) When dealing with young or short trees (twice helicopter height or less), the most densely and evenly wooded area should be chosen. This is an ideal situation in which the bottom of

the aircraft as well as the main rotor provide a cushioning effect.

(3) When dealing with large trees, resistance against the bottom aircraft structure should be avoided in such a manner that the fuselage and tail boom will settle between the tree tops before the main rotor engages the branches of the surrounding trees. In other words, the pilot should look for an area where the rotor disk meets e^ual resistance at tree top level with the "softest" spot for fuselage and tail boom to insure a tail-low attitude at ground contact. The general implication is that, although their branches may overlap, tree trunks should provide a clearance of at least 1 1/2 times the rotor diameter.

(4) If at all possible, main rotor contact with heavy trunks high above the ground should be avoided as it may result in loss of main rotor or transmission failure. If a retreating (metal) blade strikes very heavy lumber, the tendency of the transmission is to fail in the forward direction (with counter-clockwise rotor rotation.) The opposite is true when an advancing blade strikes a heavy obstacle, including the ground.

(5) A landing in a sparsely wooded area may re^uire more finesse than landing in a dense forest canopy since the few individual trees act as obstacles rather than energy absorbers. Under these circumstances, the terrain itself will probably be the main touchdown area and hitting an obstacle prior to touchdown often leads to loss of aircraft control and an uncontrolled crash. For example, if the left side of the rotor disk were to settle into trees while the right side met no resistance, the aircraft would tend to strike the ground on its right side.

(6) Brush-type vegetation of less than helicopter height should be dealt with as if it were not there.

(7) Clearings in woods should be treated with caution as they may contain tree stumps and other obstacles that may penetrate the aircraft's bottom.

(8) Dead trees are dangerous; they offer little energy absorption and tend to puncture the fuselage.

(9) A tree landing should be executed with zero or near-zero groundspeed and in a tail-low attitude. If for some reason the pilot is unable to reduce forward velocity to safe limits and tree contact is unavoidable, he should flare the aircraft in an extremely nose-high attitude against the densest growth and as close to the ground as possible. In this case, the pilot is using the trees to absorb energy of motion in the horizontal plane and the bottom of the aircraft becomes the main contact point as well as a protective shield. Even individual trees--preferably the smallest ones--can be used for this purpose if the center of the aircraft is aimed at the center of the tree crown. Uprooting a tree under these conditions adds to the impact attenuation process, as shown by accident experience.

As far as less yielding obstacles and man-made obstructions are concerned, the same concepts apply: Avoid nose-first contact under all conditions and avoid destruction of the main rotor until the aircraft is close to the ground and/or the forward velocity is negligible.

Terrain covered with obstacles: Should the pilot detect rocks, logs, etc., at his intended touchdown point, he will make every attempt to maneuver the helicopter to avoid straddling obstacles at ground contact. In other words, the touchdown should not be made over any obstacle with dimensions smaller than the width of the skid gear.

Sloping terrain: In attempting a landing on sloping terrain, it should be made up-slope. In other words, with the skid gear parrallelling the slope of the terrain. Again, it is better to attempt a landing up-slope than one down-slope.

Water landings: If it becomes absolutely necessary to make a landing over water, the pilot should make every effort to land as close to the shore as possible. During the approach, which should be made into the wind, the pilot should attempt to turn off the switches, and jettison the doors. Prior to water contact, he should execute a full flare and reduce airspeed to zero. Collective pitch should be applied to cushion the landing. After the helicopter is in the water, it should be rolled either to the right or the left to stop the rotor. And then the pilot should clear immediately.

The last consideration is wires. In the case of wires, the uestion is often asked, how should wires be contacted? Generally, if the pilot sees that wire contact is inevitable, it is best not to hit the wires with the aircraft in an unusual attitude or with a turning movement, due to the pivoting and unpredictable gyrations which would be uncontrollable with such wire contact. Again, generally speaking, the attempt should be made to maneuver the helicopter only with collective--raising the collective or lowering the collective, if evasive action is attempted. He should remember to avoid making large cyclic movements or anti-torque pedal corrections.

A final word on precautionary landings (when further flight is considered inadvisable). A helicopter precautionary landing is executed in the same manner as a force landing (when further flight is impossible), except that available power is used for touchdown. Do not hesitate to make a precautionary landing if you encounter any in-flight malfunction which cannot be analyzed.

SUMMARY

It is a fact that the helicopter has its greatest crash resistance along the vertical axis. Therefore, the forward or ground speed at touchdown should be reduced to zero if possible. This decreases the chances of tumbling or rolling after touchdown, and crushing of the light cockpit cabin structure. In addition, it prevents forward displacement of the heavy aircraft components (engine, transmission, etc.,) into the cockpit cabin area. The more suitable the terrain, the more important the reduction of forward speed becomes. Avoid touching down while turning and remember the initial ground contact should be symmetrical. That is, the two skids should strike the ground simoultaneously. Skids are the main impact attentuating device on the helicopter, and their collapse or destruction should precede ground contact of the cockpit cabin area. A nose-down pitch attitude should be avoided at all costs. To increase the distance between the occupant and the impact point of the aircraft, it may be desirable to crash land nose-high, or on the rear half of the two skids. It goes without saying, that in any flying, the pilot should make full use of available protective equipment at all times, seat belt, shoulder harness, crash helmet, etc.

Positioning himself in the cockpit is also a major consideration for the pilot. Spinal injuries are most often caused or aggravated by flexing of the spine during vertical force application. This flexing results in stress concentration on the front edges of the vertebral bodies and lowers the tolerance to vertical deceleration. When a heavy vertical crash impact is anticipated, the aircraft occupants should try to maintain a natural curvature of the spine, by sitting back against the seat with the fulllength of the vertebral column in contact with the back seat. This is of special importance to pilots, since there is a natural tendency to lean forward in a situation of stress or anxiety.

CONCLUSION

The reader is reminded that the purpose of this pamphlet is to increase the helicopter pilot's understanding of how to avoid or minimize the hazards associated with emergency landing situations. The intent is not to instruct the pilot how to fly his aircraft or to give the impression that the reading of these contents relieves him of the responsibility to maintain his routine skills and knowledge. The concepts and guidelines presented should be seen as a tool to sharpen the pilot's judgment in the utilization of available skills and knowledge under demanding circumstances; their proper application can reduce our already low occupant fatality rate (1%) in emergency landings to zero.