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A STUDY OF THE DESIRABILITY AND FEASIBILITY OF IN-FLIGHT ESCAPE FROM ARMY HELICOPTERS

November 1977

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APPLIED TECHNOLOGY LABORATORY
U. S. ARMY RESEARCH AND TECHNOLOGY LABORATORIES (AVRADCOM)
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This report reviews the feasibility and desirability of helicopter emergency escape systems from the Army's viewpoint. Accident statistics, nap-of-the-earth flight, human reaction times, and crashworthy designs are considered, and the positions of various U. S. Army organizations are included. The escape systems reviewed include ejection and extraction seats, and passenger helicopter systems.

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PREFACE

In recent years, the Department of the Navy has been researching and developing in-flight escape systems for helicopters, and in some instances, there have been joint sponsorships with the Department of the Army, primarily in the form of funding support.

At the direction of the Office of the Deputy Chief of Staff of Research, Development and Acquisition (ODCSRDA), the Applied Technology Laboratory, U.S. Army Research and Technology Laboratories (AVRADCOM), has conducted this in-house study to assist in determining whether further Army efforts are warranted in connection with in-flight escape systems. In order to accomplish this, it was necessary to investigate the Army's need for and the technical feasibility of such a capability. In the course of this study, all pertinent reports and current developments were reviewed. Private industry, the Naval Air Systems Command (NASC), the Naval Air Development Command (NADC), the National Aeronautic and Space Administration (NASA), the Training and Doctrine Command (TRADOC), and the Army operational community in general were contacted for input.

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INTRODUCTION

The idea of providing an in-flight escape system for helicopters has been considered since the advent of the helicopter. It has evoked a full spectrum of opinions and raised serious questions dealing with technology and economics.

The study reported here was conducted to review these questions from the Army's standpoint in order to explore the Army's need to continue research into such escape systems. To do this, the Army's use of helicopters was reviewed, and the requirements that this use placed on escape systems were considered. The ability of present technology to meet these requirements was considered, and the shortcomings were evaluated with respect to the needs.

ARMY AVIATION

Army aviation, because of its unique role in the combat zone, requires aircraft with vertical takeoff and landing (VTOL) characteristics, rather than the characteristics of the standard Air Force or Navy fixed-wing aircraft. Army rotary-wing aircraft play a very active role in providing maneuverability, logistics, and fire power in rapidly changing combat situations. It is appropriate that the Army consider in-flight escape systems relative to this environment. As a result, in-flight escape systems have been assessed as to how they apply to the nap-of-the-earth (NOE) flight environment and whether they apply to fixed-crew or passenger helicopters.

NOE flight techniques are the result of experience in the Republic of Vietnam and the 1973 East Arab/Israeli War, which showed that helicopters could effectively attack armor in high-threat environments if they used terrain flying techniques such as NOE.[1]

The NOE flight envelope is referred to in this report since it places the most severe restrictions on flight escape systems. NOE flight is typically between 0 and 60 feet above the ground and between 0 and 60 knots. Although these limits are not rigidly defined by the Army, they are believed to be reasonably implicit in NOE flight.

Another important consideration in the evaluation of the Army's need for escape systems is their applicability to passenger helicopters. Passenger and fixed-occupant helicopters require different systems, so the Army would have to develop at least two types of systems to cover its helicopters.

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[1] Headquarters, Department of the Army, *Terrain Flying*, FM 1-1, October 1975.

EXISTING EMERGENCY PROCEDURES

Autorotation

Presently, the only emergency technique used to counter selected in-flight emergencies is autorotation. Autorotation depends on five factors: pilot response and training, aircraft altitude and speed during failure, aircraft autorotation characteristics, terrain at emergency site, and type of failure.[2] Some of these factors—autorotation characteristics and aircraft altitude and speed during failure—are related in the plots of Figure 1, which emphasize autorotation in NOE conditions. As indicated by these plots, approximately half of the altitude/airspeed conditions do not permit autorotation, eliminating this procedure from use during many emergencies in NOE. Other factors, such as wires, trees, towers, and rough terrain, further restrict the use of autorotation.

Manual Bailout

The use of the personnel parachute would be the simplest available method for in-flight escape, but because of its probability of success, manual bailout has not been considered a viable means of escape in helicopter emergencies. Although bailout from an autorotating helicopter is possible at high altitudes, it is still dependent on autorotatable conditions, which in most cases would eliminate the need for bailing out.

Under emergency conditions, a helicopter can easily enter a completely uncontrolled state. Safe exit from the cockpit becomes extremely difficult under such conditions, if not impossible. Then, even if cockpit clearance is achieved, the rotor is a serious hazard. Added to this, the altitude and airspeed restrictions on bailing out from a helicopter are stricter than for airplanes. Successful parachute operations from an airplane at 100 feet altitude and with 70 knots forward speed have been reported, but a 200-foot altitude is probably the minimum at which a safe escape from a helicopter could be achieved at low airspeeds.[3] Even this situation would require good egress conditions. These criteria render manual bailout unlikely in the terrain flight environment.

[2] Arnold, J. H., and Pollard, B. F., *Emergency Helicopter Crew Passenger and Vehicle Survival and Recovery Techniques*, SAFE Engineering, June/July 1965, pages 10-12.

[3] Advisory Group for Aerospace Research and Development, Report No. 62 on *Escape Measures for Combat Helicopter Crews*, August 1973.

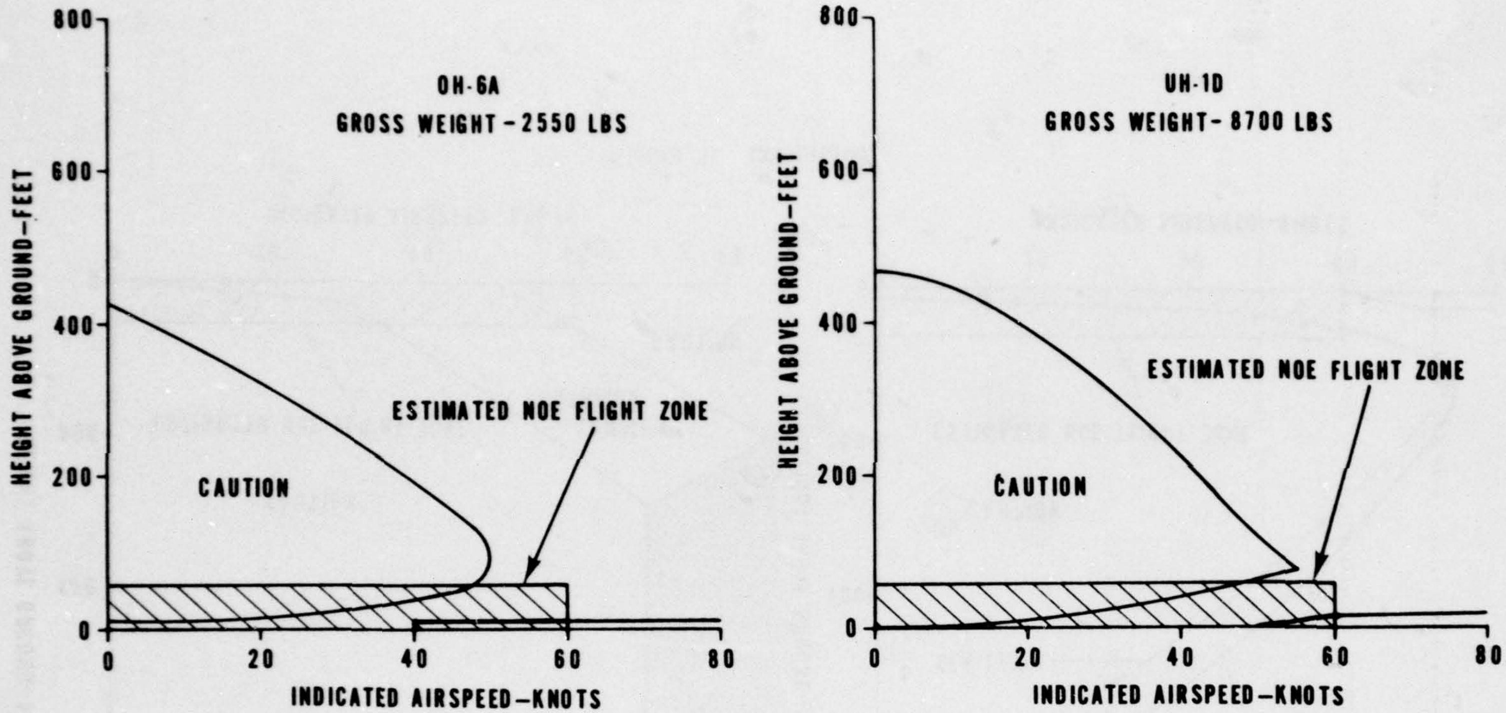

Figure 1. Autorotation curves.

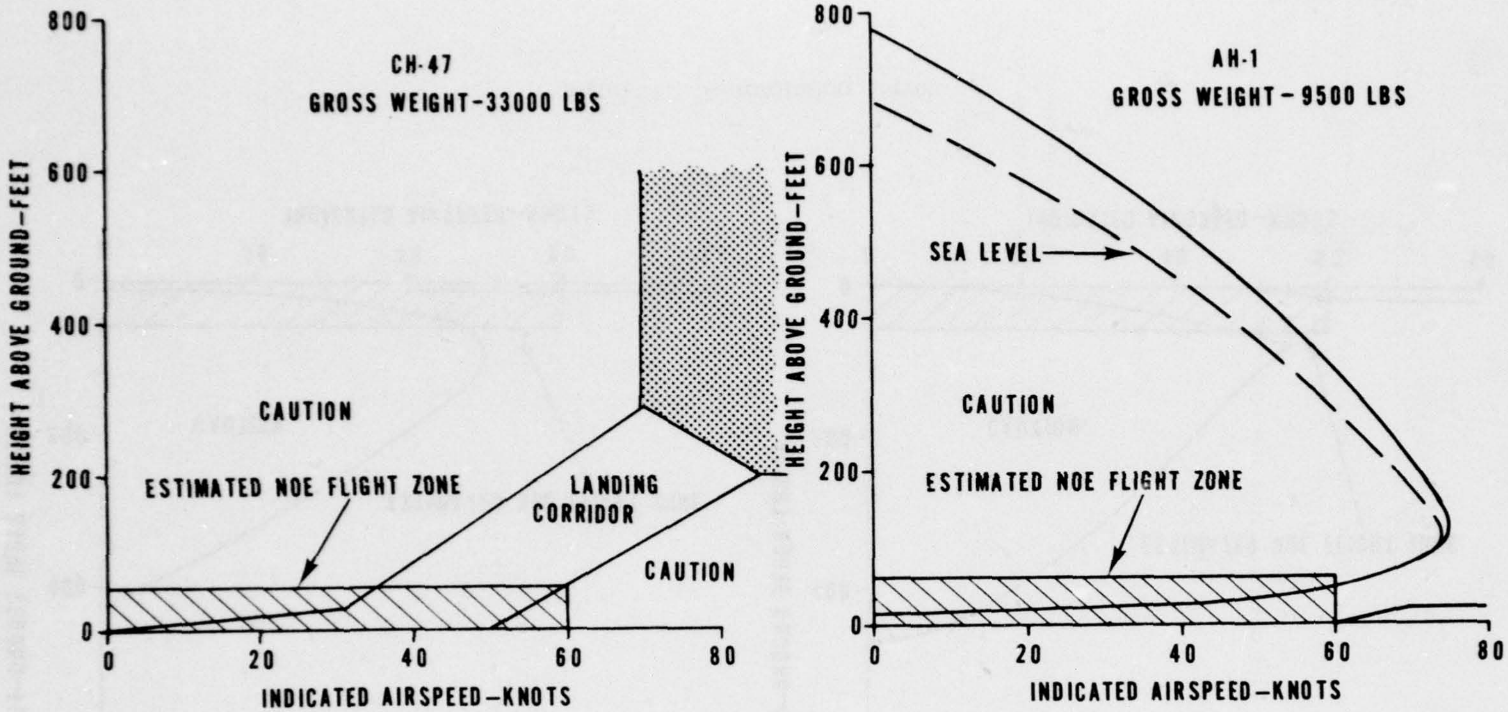

Figure 1. Continued.

ESCAPE SYSTEM TECHNOLOGY REVIEW

Three escape system concepts are being considered for application to helicopters. Two, the ejection seat and the extraction systems, are for fixed-passenger helicopters, such as attack and observation helicopters. The other system, a capsule system, would be applied to passenger helicopters so that the passengers and crew could be saved with the same system and so that all would have the same protection. The feasibility of blade removal, which is necessary to the escape systems, is also discussed here.

EJECTION

A lightweight, rocket-assisted ejection seat would be a viable candidate for a helicopter escape system because it could be tailored to a single-mode, low-speed escape in order to satisfy many of the emergency situations encountered in helicopter mishaps, such as high sink rates, adverse attitudes, gyrations, and zero altitude and speed. Furthermore, the systems have proven reliability: the ejection survival rate has run as high as 89 percent in fixed-wing aircraft.

Ejection seats have already achieved widespread acceptance in VTOL and rotary-wing research aircraft. For example, the X-19 VTOL craft had a North American LW-2B series seat that allowed the crew to successfully eject at 390 feet, inverted, during an emergency. Analysis of films reveals that a safe recovery could have been made from as low as 160 feet. Among other research aircraft, the Tilt Rotor Research aircraft has an LW-2B ejection seat, and the XV-4 and XV-5 aircraft had ejection systems.

Ejection seat performance is initially dependent on the aircraft's spacial position and dynamics, but after cockpit clearance, seat performance is independent of further aircraft motion. As a result, high roll and yaw rates do not impede or limit this portion of the ejection. However, complicated manual operations cannot be carried out by the pilot when linear accelerations are over 2g's or rotational velocities exceed 2 or 3 radians per second.

A very favorable performance envelope is attained when the parachute is deployed by a drogue slug, or other forceable means, immediately after seat/helicopter separation (Figure 2). This feature minimizes the time between separation and parachute deployment, which must be kept to a minimum for maximum recovery probability. It is estimated that this time would be slightly less than 2 seconds when opened forcibly (Figure 3). Low-speed flight makes this quick deployment possible; however, similar results can be attained with a seat-pan parachute and a static-line deployment configuration.

Figure 2 is a composite of performance data of two current-technology seats modified to represent the performance bands of a generic lightweight seat. The band widths indicate performance variations as affected by aircraft airspeed over a range of 0 to 100 knots. Given a particular attitude, successful recovery can be accomplished at any of the combined sink-rate/altitude conditions located above the attitude band in the X-Y plane. It is noted that performance degrades as the attitude angle increases.

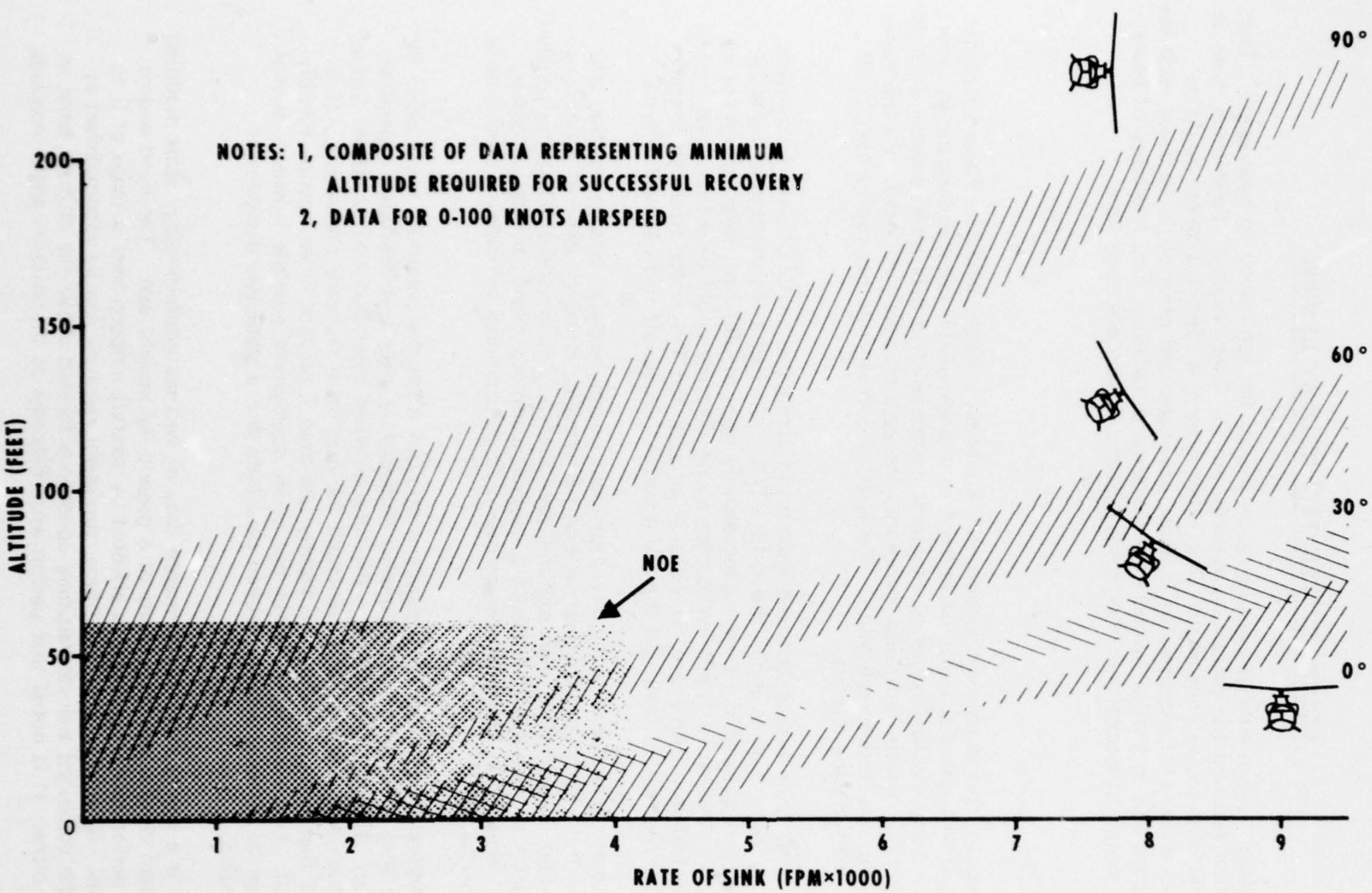

Figure 2. Generic lightweight ejection seat performance.

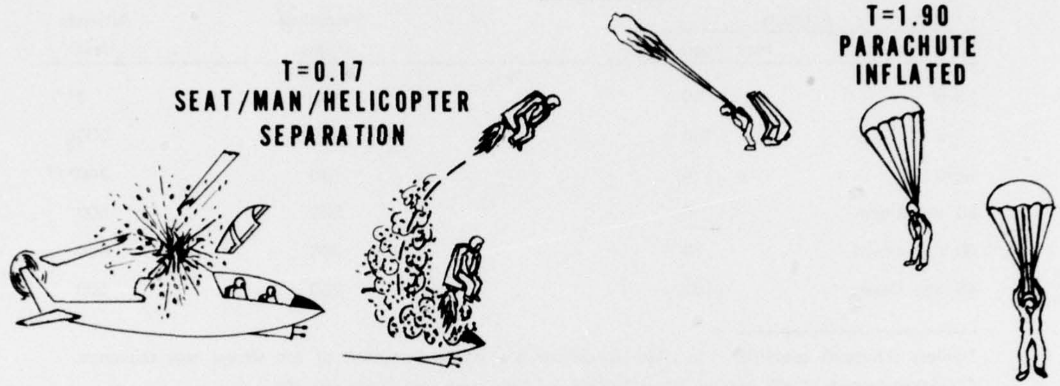

Figure 3. Upward ejection seat operation sequence (typical).

An estimated NOE flight zone is superimposed to show the relationship of the ejection seat's performance to the probable flight conditions. Although not shown in Figure 2, escape from inverted flight can be achieved from approximately 140 feet when the airspeed and the sink rate are both near zero.

Ejection seats are not well suited for retrofitting because this would require extensive airframe modifications; however, if ejection seats were chosen for use in future helicopters, they could be included in the design, avoiding the difficulties of retrofitting. One design feature of the seats is that they do not require any special provisions for removing, severing, or fracturing the canopy because they can "punch through" unaided.

EXTRACTION

The helicopter emergency egress system most recently investigated by the Army and the Navy used a technique developed by Sikorsky Aircraft and Teledyne McCormick Selph, the Yankee extraction system. This system was originally developed by the Stanley Corporation for the Air Force's T-23 and A-1E/H/J. Presently, USAATL has contracted Stanley Aviation and Sikorsky Aircraft for an extraction system, including rotor blade removal, for their Rotary Systems Research Aircraft (RSRA). Stanley Aviation is to supply a system to provide upward egress for three crew members. It is noted that these systems are not specifically designed for low-speed, low-altitude flight. The performance criteria for the RSRA system are shown in Table 1.

TABLE 1. LOW LEVEL ESCAPE PERFORMANCE*

Attitude		Velocity	Altitude
Fore and Aft	Roll Angle (deg)	(keas)	(feet)
Level	60	120	0**
Level	180	150	200
Level	0	150	300***
60 deg Down	0	200	500
60 deg Down	60	200	550
45 deg Down	180	250	600

*Unless otherwise specified, the cited conditions are at the initiation of the escape seat sequence.

**Impact occurs at the instant of separation of man and seat from aircraft.

***10,000 feet per minute sink rate.

The extraction system functions as follows: upon initiation; a ballistic cartridge is fired that generates high-pressure gas in the rocket launcher and propels the extraction rocket out of the aircraft in a nonburning state. The rocket is secured to the crewman by two pendant lines that are fastened to his torso harness. After the extraction rocket is launched, these pendant lines become taut, and the rocket ignites and pulls the crewman clear of the aircraft in a standing position. A static line connects the crewman's parachute apex to the airframe in order to insure line stretch. The parachute is then inflated aerodynamically. Just prior to burn-out, the rocket is automatically released. The operation sequence is depicted in Figure 4.

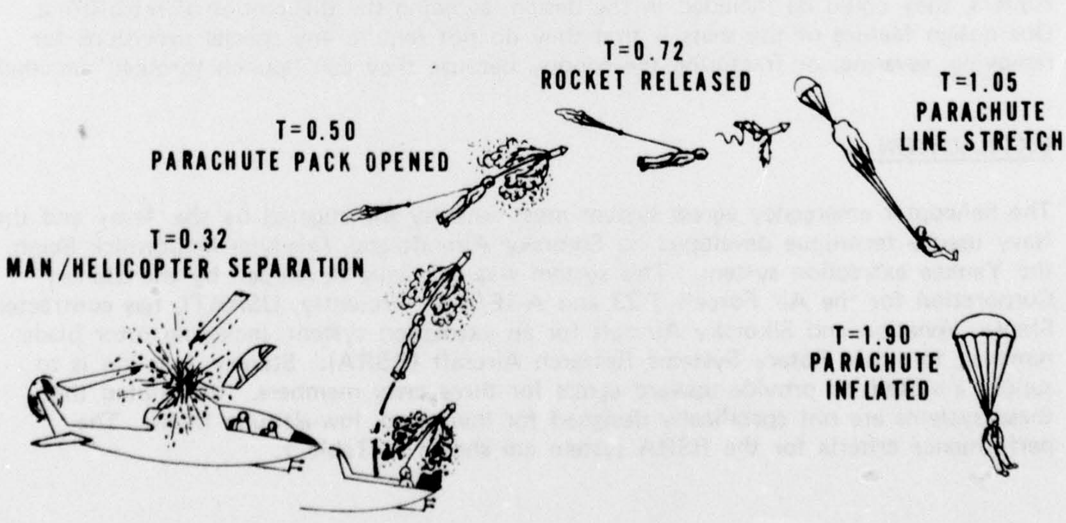

Figure 4. Upward extraction system operation sequence (typical).

One questionable area with this design is the static line being attached to the airframe. Of primary concern is whether high roll rates or other adverse aircraft dynamics would affect parachute deployment or development and result in entanglement or malfunction.

Under Navy contract, Bell Helicopter conducted a study to determine the feasibility of using the extraction concept for an escape system on the AH-1.[4] Bell Helicopter developed and constructed a preliminary AH-1 escape system performance chart (Table 2) from computer, accident, and flight mode data and Specification XAS 3702.[5] Engineering estimates and limited test data were compiled and are shown in Figure 5 to indicate the lower boundaries of the extraction system's successful escape envelope. These boundaries appear to be practical for such a system. As in Figure 2, for a particular attitude, successful recovery can be expected in conditions located above the attitude line. An estimated NOE flight zone is superimposed to relate the escape capabilities to potential low-altitude flight emergencies.

The feasibility of an extraction system has been unquestionably proven and demonstrated, as outlined in References 4, 6, and 7. Although this scheme is the most compatible system for the AH-1, the limited test data and sketchy performance estimates cause serious questions about its performance in a low-altitude emergency condition.

UTILITY AND CARGO HELICOPTER CAPSULE ESCAPE SYSTEMS

Accident statistics show that approximately 90 percent of the fatalities experienced in the 1969 to 1975 time frame occurred in passenger-carrying helicopters. This reveals that only 10 percent of the fatalities could be addressed by the use of ejection seats, which have the most advanced state of technology. Therefore, for maximum applicability of escape systems to Army fatalities, a recovery system for passenger-carrying helicopters would be required.

The feasibility of a helicopter escape system in which the occupied portion of the helicopter can be recovered from a high-altitude emergency was demonstrated by three drone UH-25B helicopters in a Navy study.[6] In this project, a capsule escape system was developed for and installed in obsolete UH-25B helicopter test vehicles configured for remotely controlled flight. Three successful in-flight tests of the system were conducted between March and June of 1966.

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[4] Bell Helicopter Company, *AH-1 Crew In-Flight Escape System, Phase I Study*, Final Report 209-099-445, October 1974.

[5] Naval Air Systems Command, *Experimental-Development Specification XAS 3702, System Aircrew Automated Escape for AH-1 G/J/Q Helicopter*, Department of the Navy, 26 March 1973.

[6] Sabatini, J., *COBRA AH-1 Escape System Development Program Documentation*, Naval Air Development Center, Report No. NADC-74111-30, Naval Air Systems Command, Washington, D. C., 6 May 1974.

[7] Wiseman, R. D., Sizemore, J. A., Baker, W. H., and Stanton, J. V., *Feasibility of an In-Flight Escape System for the AH-1 Cobra Helicopter*, TR-2627, U. S. Naval Weapons Laboratory, Dahlgren, Virginia, October 1971.

TABLE 2. PRELIMINARY DESIRED PERFORMANCE OF AH-1 CREW IN-FLIGHT ESCAPE SYSTEM

Flight Condition	Altitude (feet)	Speed (keas)	Rate of Climb or Sink (fpm)	Attitude (Deg)			Rates (Deg/Sec)		
				Pitch	Roll	Yaw	Pitch	Roll	Yaw
Hover	0	0	0	0	0	0	0	0	0
Control Failure	75	0	0	0	45	0	0	60	0
Loss of Tail Rotor	150	0	-1000	0	0	180	0	0	100
Autorotation	100	60	-2000	-5	0	0	0	0	0
Climb-out	75	100	+2000	+20	45	0	0	100	0
Low-Speed	50	50	0	-20	0	0	-25	0	0
Loss of Tail Rotor	0	50	0	0	0	R90	0	0	100
	100	50	-2000	-20	0	L90	0	0	100
Backward Flight	0	30	0	-5	0	180	0	0	100
High-Speed									
Loss of Tail Rotor	0	150	0	-10	0	R25	0	0	50
Loss of Main Rotor	200	150	0	-10	45	0	0	200	0
	100	150	-2000	-15	0	L45	0	0	100
Attack									
Overspeed	300	225	-6000	-20	0	0	0	0	0
	100	150	-2000	+10	0	0	0	0	0
Rolling Pull-up, Loss of Tail Rotor	0	120	+1000	+20	0	R45	0	0	100
Inverted	200	100	0	+20	180	0	0	50	0

NOTES: (1) R for yaw nose right; L for yaw nose left.

(2) Table from Reference 5.

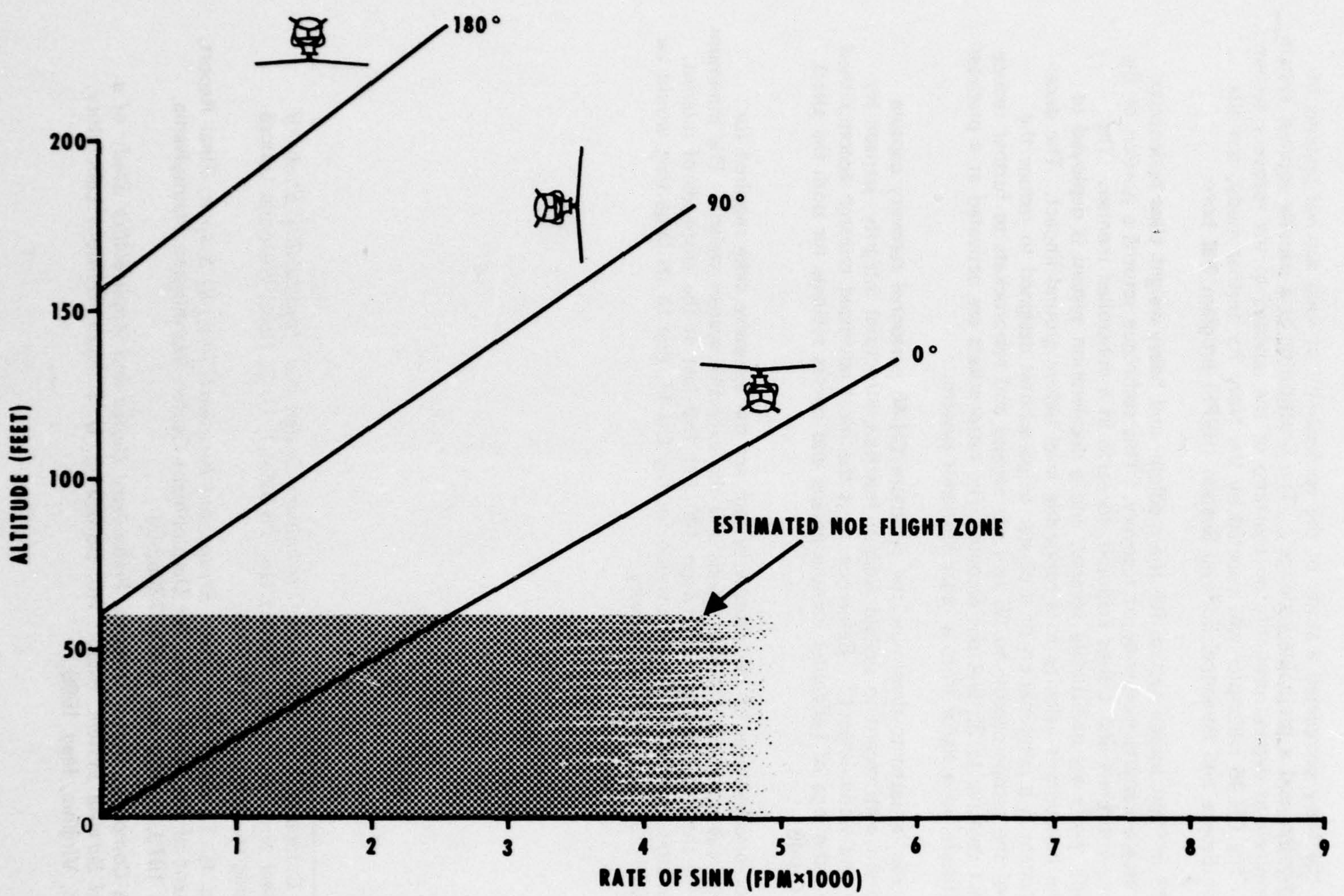

Figure 5. Estimated performance for a prospective extraction system (assume zero airspeed).

In 1968, the Navy completed a study of the applicability of such survival systems to their helicopters and a preliminary design.[8] The practicality of a capsule survival system was determined to depend primarily on the ratio of the payload to the recovery system weights. The CH-46 helicopter was selected by the Navy for further study, and the Helicopter Escape and Personnel Survival System (HEPS) program was born.

The HEPS in-flight escape system for the medium- and heavy-weight class helicopters uses the escape capsule technique of recovery. This technique returns a portion of the helicopter, with crew and troops enclosed, to earth in a controlled manner. The helicopter's rotors are ballistically severed, and a deceleration system is deployed to reduce the helicopter's velocity to a survivable level before ground impact. The deceleration system is a combination of a cluster of parachutes designed to reduce the velocity of the escape capsule to 65 feet per second and retrorockets to further reduce the impact velocity to 35 feet per second. The retrorockets are activated at a predetermined altitude by a signal from a radar altimeter system.

A study was initiated to determine the optimum CH-46 personnel recovery capsule configuration with regard to system weight, function, structural integrity, jettison trajectories, and water impact.[9] Reference 10 is the most advanced research accomplished to date in the area of helicopter capsule escape and covers systems for both the UH-1 and the CH-46.

The major disadvantages of the capsule system are the excessive time required for deploying large parachutes at low speeds and the excessive system weight. The minimum altitude for the UH-1 would be between 100 and 150 feet at the airspeeds of interest. It is estimated that the minimum altitude for the CH-47, due to its large size, would be in excess of 250 feet for safe recovery.

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[8] Boeing Company, Vertol Division, *Preliminary Design and Applicability Study of a Personnel Survival System*, Report No. D8-0924-1, U. S. Naval Weapons Laboratory, Dahlgren, Virginia, May 1968.

[9] Thomas, G. T., *HEPS (Helicopter Escape and Personnel Survival) System*, Final Report, Department of the Navy, Naval Air Development Center, Warminster, Pennsylvania, 1 March 1973, Report No. NADC-73052-50.

[10] Boeing Company, Vertol Division, *Preliminary Design and Applicability Study of a Personnel Survival System*, Report No. D8-0924-2, U. S. Naval Weapons Laboratory, Dahlgren, Virginia, May 1968.

SUBSYSTEMS

With either the upward extraction or the ejection seat escape system, a number of subsystems may be required, such as rotor severance, canopy jettison, fuel-to-engine shutoff, and an explosives energy transfer sequencing device to initiate all the functions. The feasibility of these subsystems was established by the Navy in a COBRA escape system development program.[6] In this program, a ballistic subsystem consisting of a design that would provide a clear escape path for extracted crewmen was almost finalized in a hardware form.

One of the key concerns with the overall concept is the rotor blade hazard, but the Advisory Group for Aerospace Research and Development (AGARD) maintains that severing a rotor blade or a hub is not a serious problem.[3] The reliability of explosive-actuated systems has been proven. All necessary elements for severance have been used extensively. The linear flexible explosives used are unaffected by electromagnetic and thermal radiation, impact, and temperatures in excess of 500°F. They will not explode in a fire but will burn or melt. Lightning will not set them off, and they cannot be ignited by lasers, shrapnel, or large-caliber projectiles.

Rotor blade severance, considered only a moderate technical risk, is required by specification XAS-3702 to be accomplished sequentially in such a way that the danger to crewmen and neighboring aircraft will be minimized.[3,5] One device proposed to meet this requirement is to use a segmented slipring band for the energy transfer system assembly and to make the system programmable to allow the blade trajectories to be controlled; however, blade dynamics cannot be controlled accurately, so the blade trajectories will not be able to be controlled precisely either.

DISCUSSION OF FEASIBILITY AND DESIRABILITY

GENERAL

The desired capability of an escape system is to allow successful escape when the conditions at the initiation of the emergency are adverse attitude, sink rate and roll rate, and zero altitude and airspeed. In addition, the time delay in the initiation of the escape system due to the human response factor must be considered. Some basic characteristics of an ideal emergency escape system are:[11]

- that the system would be effective under a wide range of aircraft attitudes and velocities, particularly at very low altitudes;
- that the system would be simple, reliable, and easily maintained;
- that the system would accommodate all personnel on the aircraft, crew members and passengers alike;
- that the system would not significantly decrease performance characteristics of the aircraft; and
- that the system would be easily designed into all future Army aircraft.

The feasibility of meeting these goals completely is doubtful; the desirability of the systems must be evaluated in light of their shortcomings. The main problems that are foreseen are weight, cost, effectiveness, and human response times, and these are discussed below.

WEIGHT

Probably the strongest argument against in-flight escape systems for gunship, observation, and training helicopters is the weight of such systems. Escape systems add to the aircrafts' empty weights and are not considered useful loads since they do not improve aircraft life, logistic capabilities, or mission stay times.

To date, there are no official Army guidelines or requirements concerning the weight of an escape system. About 100 pounds or 1 percent of the gross weight has been estimated to be a reasonable system weight for a two-man gunship.[5] It is assumed that this percentage would hold for observation and training vehicles as well. Presently, an emergency ejection-seat system for a fixed crew of two installed in a future attack helicopter would result in a weight penalty of 160 pounds. For a similar extraction system, the penalty would be approximately 130 pounds.

If escape systems were required for gunships, the additional weight would have to be compensated for. Assuming that the weight would be traded out of the fuel capacity,

[11] Littell, D. E., Bailey, R. W., and Schane, W. P., *Escape System Requirements for U. S. Army Aircraft in Vietnam*, USAARL, date unknown.

the result would be a 10-percent reduction in the maximum range capability. Regardless of whether the weight is traded for fuel, ordnance, or armor, this significant weight increase would force a significant compromise in the aircraft's capabilities.

The weight penalties for capsule systems for passenger and cargo helicopters are much greater. With a HEPS system, the weight penalty for a UH-1 was estimated to be between 230 and 300 pounds, or up to 34 percent of the payload.[8] A HEPS system for the CH-47 could run as high as 2,350 pounds or 22 percent of the payload.[10]

COST

Although the figures discussed in this section are not current, they are adequate to establish the magnitude of the expense involved in escape system development.

One vendor estimated that the funds needed to develop and qualify an in-flight escape system for the AH-1 would be over five million dollars.[4] It was further estimated that the cost of outfitting a single AH-1 would be in excess of $25,000. The cost of outfitting a fleet of 622 AH-1s amortized over 10 years would be $1,555,000 per year.

In 1972, the Aeronautical Systems Division of the Department of the Air Force prepared a program to provide the UH-1 with an in-flight escape system.[12] It was determined that a research and development program for a modular capsule for the UH-1 using parachute and retrorocket recovery would cost $3,667,000 and the hardware and installation would cost $50,000 per aircraft. Based on these figures, the cost of outfitting the Army's fleet of 2,391 UH-1s amortized over 10 years would be $11,955,000 per year.

An escape system with good cost-effectiveness should have a high ratio of probable saves to its cost. This ratio depends upon the use of the helicopters: based on combat statistics, the ratio would be higher, reflecting more saves for the costs; but during peacetime, the ratio would be lower, reflecting fewer saves for the costs. In either case, the costs would be considerable and the magnitude of these costs may very well be prohibitive considering the limited number of saves the systems could effect.

HUMAN FACTORS

Response Delays

Although ejection and extraction systems vary somewhat, in general the crewman goes through the same series of steps to use them. With an automatic ejection system, once the decision to evacuate has been made and the system has been fired, the ejection of the pilot and the deployment of the parachute are automatically controlled. The pilot is no longer an active participant in the sequence of events. However, the pilot's part is very important.

[12] Aeronautical Systems Division, Department of the Air Force, *Egress From Rotary-Wing Aircraft*, Wright-Patterson Air Force Base, Ohio, 9 July 1971.

The first step in the decision to eject depends upon the recognition of the emergency. Because of the number of warning lights that must be assessed and the fact that the need to eject often occurs when the pilot's attention is on some other activity, the actual realization of the seriousness of the situation may be delayed. On the other hand, it can be assumed that the higher the altitude of the aircraft when the situation is recognized, the longer the situation may be analyzed and, consequently, the greater the chances for a successful ejection.

In many cases, the emergency is known to have occurred at an altitude sufficient to allow an ejection with a high probability of survival but the pilot failed to eject or waited until too low an altitude. This indicates that many individuals delay making this decision, and this delay is the result of a combination of factors. In some instances, it represents a faulty interpretation of the seriousness of the emergency. In others, it indicates overconfidence on the part of the pilot, who feels that he can maintain control of the situation and continue flight or that he is quite capable of crash-landing the aircraft with a minimum of damage and personal injury. At times, it reflects over-concentration on the details of the activity in progress. In other instances, delays reflect the confusion the pilot experiences in this suddenly changing situation.

In the design and application of an escape system, the question arises: what time does a pilot need in a given emergency situation to decide on ejection? Unfortunately, it is impossible to simulate aerial emergencies so that the pilot is exposed to the same mental and physical stresses as in the real world. To approach the actual conditions, tests were performed with a simulator for the USAF VTOL fighter VJ 101 C-X2.[13] Results showed that ejection decision times varied from .6 to 22 seconds, depending primarily on the type of aircraft system failure.

When faced with a sudden and critical crisis and especially during NOE flight, the fleeting seconds available to effect a successful escape and recovery are few indeed. In spite of available egress system technology, the final decision to eject lies with the pilot, and such decisions take time. For example, in the case of an engine failure, the decision to eject would take approximately 1 second. This, coupled with 1.5 seconds for access and ignition, results in a 2.5-second delay from engine failure to seat/aircraft separation. This time can be significantly increased by indecision and confusion, depending on the individual and the circumstances.

The time it takes to respond is extremely important and must be considered in the assessment of an escape system's effectiveness, especially for systems meant to be effective at low altitudes, where even a 2.5-second delay could be critical.

Pilot Performance and Escape Systems

A study prepared by the U. S. Army Agency for Aviation Safety documented the feelings of 152 AH-1 aviators concerning the need for an in-flight escape system on the AH-1

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[13] Hahn, Peter, *Simulation Study to Determine the Ejection Decision Time During Takeoff and Landing of the VJ 101 C-X2*, Foreign Technology Division, Wright-Patterson Air Force Base, Ohio, September 1971, AD 890-015L.

aircraft.[14] Responses showed that nearly 60 percent of the pilots have experienced in-flight situations in which they felt anxiety would have been reduced had an in-flight escape system been available. This finding was considered to be significant since anxiety has a serious effect on an individual's motor skills and judgment.

Overall, the findings of this study were especially interesting inasmuch as an Army aviator's indoctrination and training does not orient him to in-flight escape. However, the responses indicated that AH-1 pilots do perceive a need for such a system to improve their chances of surviving certain emergency situations. The most clearly voiced feeling was that the AH-1 should have such a system for situations in which the aircraft has lost power or control and the circumstances preclude a safe landing. The study found that 94 percent of the pilots surveyed thought that attack helicopters should be equipped with in-flight escape systems.

Measures of Effectiveness (MOE)

When addressing the measures of effectiveness for in-flight emergency egress equipment, the list is brief. Unlike so many proposed safety and survivability equipment schemes that can and do serve to improve aircraft staying power by reducing aircraft detection, an in-flight escape system stacks up as a liability in terms of mission or strategic factors. We can measure escape system benefits only by the number of lives that could be saved, which would be the most profound reason for the systems.

AGARD and the GAO have reported worldwide helicopter accident figures and referenced Navy accident study statistics that establish that between 40 and 60 percent of all helicopter fatalities from 1958 to 1972 could have been prevented if adequate in-flight escape systems had been provided; furthermore, most of these fatalities occurred during noncombat operations.[3,15] Assuming, in accordance with earlier studies, that 50 percent of Army fatalities could be prevented by escape systems, 576 of the 1,153 fatalities from 1969 to 1975 could have been prevented. These figures include all Army helicopters, generally totaling between 4,000 and 6,000 aircraft.

However, crashworthiness design developments currently being incorporated in the new generation of Army helicopters are predicted to significantly reduce the probabilities of accident fatalities. For instance, in a cost and operational effectiveness analysis of the UTTAS, the 138 major aircraft accidents that occurred during the 1972-75 period were analyzed, and it was predicted that the accident rate in a UTTAS-type aircraft would be reduced 40 percent and that the number of occupants killed or injured could be reduced from 45 to 29 percent.[16] Therefore, the likelihood that an escape system would be required during an emergency in a crashworthy helicopter is less than in a helicopter without these features.

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[14] Johnson, Paul H., and Lindsey, Dwight, *AH-1 Helicopter Escape System: A View From the Seat*, USAAVS Technical Report 76-1, U. S. Army Agency for Aviation Safety, Fort Rucker, Alabama, February 1976.

[15] Comptroller General of the United States, *In-Flight Escape Systems for Helicopters Should Be Developed to Prevent Fatalities*, GAO, June 12, 1973.

[16] Hicks, J. E., *Economic Benefits of Utility Aircraft Crashworthiness*, USAAVS Technical Report 76-2, U. S. Army Agency for Aviation Safety, Fort Rucker, Alabama, July 1976.

Although current accident statistics support the rationale for in-flight escape systems, it is predicted that the improved survivability, crashworthiness, and safety of the UTTAS, the AAH, and the ASH will have a positive effect on such statistics. This will reduce the expected benefits of in-flight escape systems.

In 1971, a Navy-contracted accident report addressed a section exclusively to Army helicopter accident statistics.[17] Again, the conclusion was that the availability of in-flight escape systems would have prevented 40.4 percent or 385 of the 953 fatalities from 1966 to 1968. Also, it was concluded that the requirements for an in-flight escape system were identical during combat and noncombat activities. It is noted that these statistics did not include accidents originating at altitudes of less than 100 feet.

These statistics are not disputed, but can current or future escape requirements or needs be evaluated or justified by dated statistics, some of which do not consider low-altitude (less than 100 feet) accidents? What effects has the NOE flight doctrine had on recent accident statistics? What is the current rate of incidence of low-altitude accidents? What effects will crashworthiness measures and twin engines have on the predicted number of lives to be saved by escape systems?

As expected, the trend has been toward a greater percentage of Army accidents being at altitudes of less than 100 feet. Table 3, acquired from USAAVS, lists the Army helicopter accident totals and the number of low-altitude accidents for the periods 1969 to 1971 and 1972 to 1975. The rate of fatalities per accident decreased about 11 percent from the earlier period to the later period, and the ratio of low-altitude accidents to all accidents increased 300 percent. Although the percentage of accidents at low altitudes in the 1972-75 period was three times that of the period from 1969-71, it is observed that 56 percent of all helicopter accidents still originated at altitudes greater than 100 feet, where escape systems exhibit their maximum capabilities.

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[17] Senderoff, Isadore, *Helicopter Escape and Personnel Survival Accident Data Study*, Boeing Company, Vertol Division, Report No. D210-10267-1, Naval Air Systems Command, Washington, D. C., April 1971.

TABLE 3. ARMY HELICOPTER FLEET ACCIDENT STATISTICS

	Accident Fatalities	Hours Flown	Total No. Accidents	Average Fleet Size	Accident Fatality Rate*	Accident Rate*	Accidents Initiated at <100 ft Alt
Combat Mobilized 1969-71							
AH-1	77	983,000	444	622	.78	4.5	27
OH-58	28	479,242	78	655	.58	1.6	23
UH-1H	598	4,782,459	809	2,392	1.25	1.7	153
CH-47	249	654,913	73	493	3.80	1.11	7
Peacetime 1972-75							
AH-1	20	320,942	87	709	.62	2.7	30
OH-58	28	1,661,573	87	1,975	.17	.52	42
UH-1H	113	2,837,653	150	3,028	.39	.52	72
CH-47	40	214,413	8	434	1.86	.37	4

*Rates are per 10,000 hours flight

ORGANIZATION POSITIONS

The reports and position letters of the Army and other Government organizations were surveyed to determine the viewpoints of other agencies.

In 1973, the Government Accounting Office (GAO) concluded the following in a draft report to Congress: "Available technology for individual in-flight (escape) systems should be applied to the design of attack, observation, and training helicopters which have fixed crews."

The U. S. Army Training and Doctrine Command took the following position in 1976: "The tactical employment of aircraft in a high threat environment at nap-of-the-earth (NOE) altitudes reduces the need for in-flight escape systems. Reaction times following a catastrophic failure would be severely limited and would reduce the time available to activate such systems. Also, current and projected fleets cannot afford a significant weight increase or any additional system that would degrade mission effectiveness.

"An in-flight escape system would only be required in the event of a catastrophic failure, and the number of such failures causing major accidents is exceptionally small and does not warrant in-flight escape systems. Survivability has been increased and vulnerability decreased with new-generation aircraft.

"Recommend further efforts toward the development of an escape system be discontinued."

In 1976, the U. S. Army Aeromedical Research Laboratory said: "A helicopter in-flight escape system could well be the most complex and costly system yet used in any aircraft; it would be pragmatic to explore all means of preventing the fatalities usually associated with helicopter in-flight breakup."

In 1976, the U. S. Army Agency for Aviation Safety agreed in principal with a requirement for an in-flight escape system for rotary-wing aircraft.

In 1973, the Director of Defense Research and Engineering said: "Even though we are always interested in ways to increase safety in flight, in-flight escape systems have not at this time been demonstrated to be the most effective method of improving flight safety considering both human life values and dollar costs."

The Advisory Group for Aerospace Research and Development (AGARD) concluded in part in a 1973 report (Reference 3): "Overview of the data on fatal accidents occurring in all participating countries shows a definite need for an in-flight escape system for combat helicopters. Apparently the emergency conditions frequently do not allow the selection of autorotative descent and dictate immediate escape from the disabled helicopter. Examination of the accident statistics revealed that the fatality rate could have been reduced significantly if an adequate escape system had been available. It is recommended that requirements for in-flight escape for combat helicopter crews be determined immediately by the appropriate authorities."

The differences in the opinions above should illustrate how unclear the issue is. The positions do not seem to be divided according to the dates they were taken or along the lines of the missions of the organizations polled. It seems more significant that the user organization, the U. S. Army Training and Doctrine Command, doubts the value of the systems and cites accident rates, decision and escape times, and weight penalties to support its conclusions.

CONCLUSIONS

Accident statistics indicate that the use of in-flight escape systems in Army helicopters would save lives, particularly in passenger-carrying helicopters. However, the benefits of such systems are difficult to assess because of NOE flight trends and the increasing emphasis on crashworthy designs.

Existing technology, as demonstrated by the Navy HEPS work, will support the development of a capsule recovery system for passenger-carrying helicopters. The state of the art is not as advanced, however, as that of ejection seats. A substantially greater development effort would be required for this type of escape system than for ejection seats. However, 90 percent of accident fatalities involve passenger helicopters, so the development of this type of system could have a higher priority.

In addition to the significant weight penalty that the capsule recovery system would impose on an aircraft, it is of little value in the Army operating environment. It is estimated that recovery of a 10,000-pound helicopter could not be effected at altitudes of less than 150 feet and recovery of a 30,000-pound helicopter could not be effected below 300 feet.

In assessing the various means of recovering personnel from fixed-occupant aircraft, it has been determined that ejection-seat technology exists that would allow safe recoveries to be made from the majority of the emergency situations encountered. Lightweight ejection seats having very broad recovery envelopes have been built, tested, and put into use, and these escape systems are suitable for the low-speed, low-altitude recovery environment. It is also noted that the inclusion of any individual escape system, particularly ejection seats, in Army helicopters would carry with it a significant weight penalty.

An extraction technique seat, although lighter and perhaps less complex than the ejection seat, has particular disadvantages in low-altitude performance and possible adverse reactions to high roll rates. Although performance criteria and test results for this type of personnel recovery system are very limited, the indication is that its performance in low-altitude emergencies would not be as good as that of the ejection seat.

Upward emergency egress from a helicopter carries with it the implicit requirement for the removal of the entire rotor or the rotor blades. All elements required for rotor severance have been demonstrated.

Another factor that affects the feasibility of personnel escape systems is the time required to initiate ejection. The time available following a catastrophic failure, especially at a low altitude, is both critical and limited. For instance, in the case of engine failure, given the minimum indecision on the part of the pilot, the time required for decision, response, and departure from the aircraft would total approximately 2½ seconds. This time could be significantly increased by indecision and confusion, depending on the individual and the circumstances. A substantially increased decision time would negate the high-performance capabilities of an escape system through delaying escape initiation to the point where recovery is no longer achievable.

Strong differences of opinion exist over the need for and the desirability of escape systems in Army helicopters. Both the GAO and AGARD have gone on record as strong proponents of escape systems. A survey of AH-1 pilots has supported that position. On the other hand, the U. S. Army Training and Doctrine Command has stated very clearly that it feels that escape systems have no place in Army helicopter operations and recommends no further escape system development. Also, the U. S. Army Aeromedical Research Laboratory's position is that other methods of preventing accidents and surviving accidents should be pursued.

RECOMMENDATIONS

It is recommended that a Department of the Army position be established regarding the incorporation of escape systems in Army helicopters. Such a position is required in order that: (a) appropriate actions can be initiated to provide the required capability or (b) the subject can be laid to rest and attention turned to other efforts.

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