NASA Contractor Report 3895
ORI TR-2384

Investigation of Technology Needs for Avoiding Helicopter Pilot Error Related Accidents

Final Report

Richard I. Chais and William E. Simpson
ORI, Inc.
Rockville, Maryland

Prepared for
NASA Office of Aeronautics and Space Technology
under Contract NASW-3554

National Aeronautics
and Space Administration

Scientific and Technical Information Branch

1985

PREFACE

This report presents the results of an investigation by ORI, Inc. of pilot error related accidents in helicopters to identify areas in which new technology could reduce or eliminate the underlying cause of the human errors. ORI drew from the aircraft accident data base at the U.S. Army Safety Center at Fort Rucker, Alabama, as the source of data on helicopter accidents.

This study was performed by ORI, Inc. as Task 16 of NASA Contract NASW 3554. The report is intended for use by the National Aeronautics and Space Administration in preliminary planning of aeronautical research.

The authors gratefully acknowledge the very helpful assistance of the U.S. Army Safety Center in providing access to the Army's aircraft accident data base as a source of data for this study. The authors also want to thank Mr. Les Kerfoot and Mr. Paul Stringer for their many helpful suggestions in the preparation of this report.

TABLE OF CONTENTS

LIST OF TABLES

SUMMARY

The pilot is cited as a cause or related factor in most rotorcraft accidents. This report presents an investigation of pilot error related accidents in helicopters to identify areas where the application of new technology could contribute to preventing or reducing the severity of such accidents. The study was conducted by ORI, Inc. under contract with the National Aeronautics and Space Administration (NASA) as an input to their aeronautical research planning activities.

At the request of NASA, the U.S. Army Safety Center (USASC) provided access to Army aircraft accident investigation reports for helicopter accidents in which human error was determined to be a cause factor. With the cooperation of the USASC staff, ORI personnel performed an in-depth review of 110 accident investigation reports, which were a randomly selected sample of 72 percent of the major (Classes A and B) helicopter mishaps attributed to pilot error during fiscal years 1981-1983. The aggregated cost estimates for the accidents included in the study exceeded $62 million and involved 33 fatalities and 155 non-fatal injuries. The data base was handled in a manner that assured that all non-technical accident specifics considered to be sensitive information were omitted.

Army aircraft accident records were used for the study for three major reasons. First, the combination of the Army's accident investigative methods and extensive use of helicopters provided an aircraft accident data base involving a wide variety of missions. These missions were performed largely by single-rotor helicopters under 10,000 pounds gross weight, and the data were considered to be sufficiently generic to allow some insight into civil as well as military helicopter accidents.

Second, the Army data base could provide a wide range of events for analysis since human error was cited by the USASC as a factor in most (75 percent) Army aircraft mishaps.

Third, other investigators had not found the data base on civil helicopter accidents to contain information of sufficient detail to adequately assess technology needs.

In conducting this study, ORI selected a task element analytical approach. This approach involved review of the accident records on a case-by-case basis to examine the human task errors and sequence of events for each mishap and assess applicable technology implications. Since more than one

technology need could be identified for some mishaps, they were classified as primary and secondary to facilitate aggregation by common groupings. The distribution by primary groupings is shown in Figure 1.

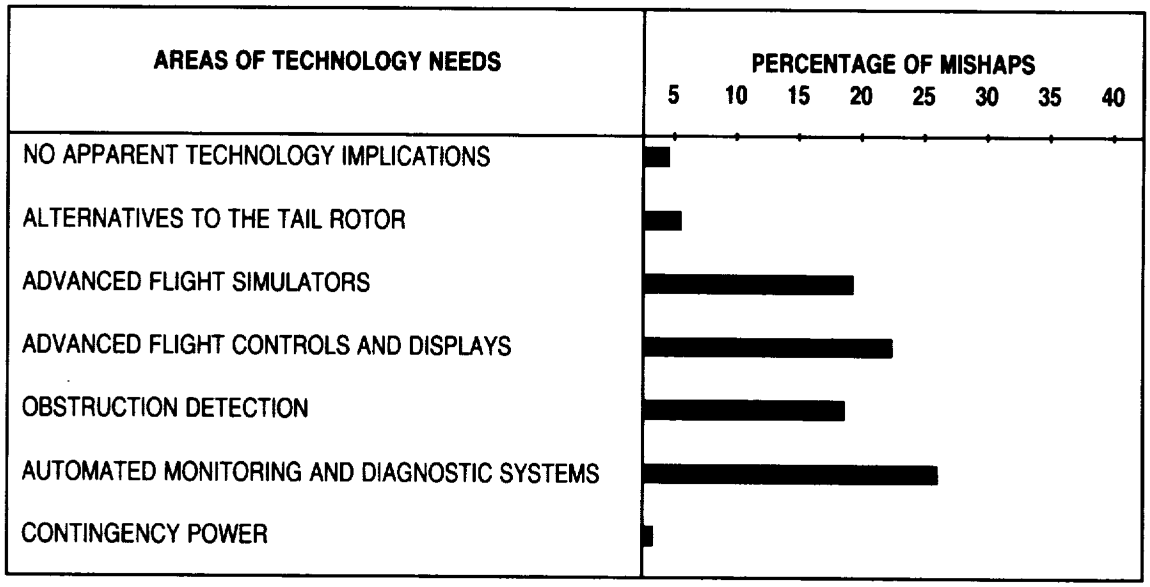


FIGURE 1. BAR GRAPH OF PERCENTAGE OF MISHAPS AGGREGATED BY TECHNOLOGY IMPLICATIONS

All of the technology implications identified from review of the 110 accident records fall into one or more of the following groups:

1. No apparent technology implications. The sequence of events leading to the mishap occurred in such a way that no apparent applications of advanced technology could reasonably be identified for a pilot-controlled aircraft.

2. Vehicle design alternatives for eliminating the tail rotor.

3. Advanced flight simulators for pilot proficiency training.

4. Advanced flight control and display systems to reduce pilot workload for aircraft control.

5. Obstruction detection devices to enhance human capability and reduce or eliminate dependence on human vision for detection, identification, and determination of distance.

6. Automated monitoring and diagnostic systems to aid the pilot in monitoring flight-critical systems, reduce cockpit instrument scan, and provide diagnostic information on conditions affecting aircraft performance (e.g., power required versus power available, trends in engine parameters, impending failure/ malfunction warning, etc.).

7. Contingency power capabilities for short use in situations where power demands required to save the aircraft exceed the rated power available.

It is recognized that product improvements using current technology can meet in various aspects some of the needs listed above, but it is apparent existing technology cannot resolve the full scope of all of these needs. Technology areas in which there appears to be a need for new or increased emphasis include:

a. Vehicle designs which eliminate or significantly reduce the hazards of the tail rotor.

b. Advanced flight simulators for pilot training in emergency procedures.

c. Advanced flight control and display systems.

d. Obstruction detection devices.

e. Automated monitoring and diagnostic systems.

f. Contingency power capabilities.

Based on the results of the review and analysis discussed in the report, the following recommendations are made for NASA consideration:

1. NASA examine research activities to plan specific tasks for advancing technologies identified in this report which can, if applied, substantially reduce pilot error as a cause factor in helicopter accidents and provide, as a benefit, the savings to be achieved by reducing accident costs.

2. NASA, in coordination with the U.S. Army, investigate the human factors aspect of pilot techniques which may involve attempts to knowingly operate an aircraft outside the design flight profile capabilities of the aircraft.

3. NASA, in coordination with the FAA, military services, and civil helicopter users, establish a task force to investigate the relationships between required pilot workload and human error as a cause factor in helicopter accidents.

I. INTRODUCTION

According to the Federal Aviation Administration (FAA), the U.S. active civil helicopter fleet has increased since 1960 at an average annual growth rate of 12.5 percent. This growing pervasiveness of civil rotorcraft usage and concern for the rate of occurrence of accidents had prompted the National Transportation Safety Board (NTSB) to conduct a special study of rotorcraft accidents.[1] The NTSB study found that the pilot is a major factor in rotorcraft accidents.[2] The NTSB cited the pilot as a cause or related factor in more than 64 percent of the 839 accidents reviewed.

In May 1984, the National Aeronautics and Space Administration (NASA), requested that ORI, Inc. investigate pilot error related accidents in helicopters to identify those areas where new technology could have been a contributing factor for avoiding or reducing the severity of the accident. This effort was initiated to assist NASA in their aeronautical research planning activities.

Discussions with the sponsors and participants in an FAA-contracted study indicated that a review of the accidents records in the NTSB data base on helicopter accidents would not provide sufficient detailed information on specific events to assess the technology implications of pilot error related accidents. As an alternative, ORI proposed that the U.S. Army's data base on helicopter accidents be used for the study if sufficient detailed information could be made available. The U.S. Army and civil helicopter fleets are comprised mostly of single-rotor helicopters with gross weights of less than 10,000 pounds. Several of the more widely used models are similar in design (e.g., Bell 206A Jet-Ranger and OH-58A), have similar flight instruments, and involve comparable pilot functions for most phases of flight. An analysis by the U.S. Army Safety Center (USASC) staff of U.S. Army aircraft accidents from fiscal years 1978 to 1982 shows that human error was the cause factor in 75

---

[1]Rotorcraft Master Plan, Baseline Report Revision No. 1, Federal Aviation Administration, May 1983.

[2]NTSB Special Study, "Review of Rotorcraft Accidents, 1977-1979," NTSB-AAS-81-1, National Transportation Safety Board, WAshington, D.C., August 1981.

percent of the major aircraft accidents experienced by the U.S. Army[3] and hence would provide a suitable data base for the ORI analysis.

At the request of NASA, the Commander, U.S. Army Safety Center, Fort Rucker, Alabama, granted permission for the ORI team to visit the U.S. Army Safety Center (USASC) and review aviation accident investigation reports to determine the nature of the data available on helicopter accidents. A preliminary visit to Fort Rucker and discussions with USASC personnel indicated that sufficient documentation was available in the USASC data base to support an in-depth analysis of the technology implications involved in pilot error related accidents.

With the cooperation of the USASC staff, ORI personnel performed an in-depth review of 110 accident investigation reports selected randomly from the 153 Class A and B helicopter pilot error mishaps which occurred during the fiscal years 1981-1983 time period. Data forms were prepared to list pertinent information concerning each mishap and an initial assessment made of technology implications of the human error aspects of the accident. This information was then summarized by mishap reference numbers on spreadsheets for further analysis and aggregation into areas of technology needs which, if advances in technology were applied, appeared to have the most promise for reducing or eliminating human error as a cause factor in helicopter accidents. Table 1 presents an overview of the results of review.

TABLE 1

SUMMARY OF HELICOPTER PILOT ERROR ACCIDENTS
AGGREGATED BY AREAS OF TECHNOLOGY NEEDS

Areas of Technology Needs	Number of Mishaps	Number of Fatalities	Number of Injuries Non-Fatal	Cost Estimates	
				Amount	Percent
No Apparent Technology Implications	5	0	15	$ 5,828,440	9.3%
Alternatives to the Tail Rotor	6	0	8	1,768,799	2.8
Advanced Flight Simulators	21	5	17	13,216,408	21.1
Advanced Flight Controls and Displays	25	8	23	15,394,824	24.6
Obstruction Detection	20	13	42	11,952,376	19.1
Automated Monitoring and Diagnostic Systems	29	7	41	12,022,725	19.2
Contingency Power	4	0	9	2,446,922	3.9
Totals for Records Reviewed*	110	33	155	$62,630,494	100.0

* Records reviewed included a randomly selected sample of 72 percent of the Class A and B helicopter mishaps attributed to pilot error during fiscal years 1981-1983

[3] Reeder, M.J., et al., "Investigation, Reporting and Analysis of U.S. Army Aircraft Accidents," Paper Reprinted from AGARD Conference Proceedings No. 347, North Atlantic Treaty Organization.

Section II of this report presents a description of the source of data and the forms used for the ORI review. The analysis of the data and assessment of technology needs are presented in the next two sections of the report. Section V presents a comparison of the technology needs with ongoing and planned research and technology activities and proposes areas for new technology. The final section presents ORI's conclusions and recommendations.

This study effort was performed by ORI, Inc. as Task 16 of NASA Contract NASW 3554.

II. DISCUSSION OF DATA SOURCE

The data base selected for this investigation of pilot error related accidents in helicopters is comprised of Technical Reports of U.S. Army Aircraft Accidents for helicopter mishaps occurring in fiscal years 1981, 1982, and 1983. In support of the objective of this NASA-sponsored analysis, the U.S. Army Safety Center provided access to Army records for helicopter accidents in which human error was determined to be a cause factor.

Army aircraft accident investigation reports are prepared and safeguarded in accordance with Army Regulation 385-40, "Accident Reporting and Records." The reports are comprised of a series of data forms (DA Forms 2397-R series) and attachments prepared by the accident investigation board assigned to investigate a specific mishap. For serious accidents which involve loss of life, disabling injuries, or extensive damage to aircraft or property, a minimum of four investigators are appointed to the accident board. At least two board members must be Army Aviators on flying status, one must be a medical officer, and the other must be an aircraft maintenance officer. Other technical skills may be appointed to the board as required to carry out the investigation.

Army accident records were used for the study for three major reasons. First, the U.S. Army operates an extensive fleet of helicopters for a wide variety of missions. The Army's aircraft accident investigative methods therefore tend to focus on acquiring and documenting information on helicopter mishaps which can be used to resolve human errors, material failures, and environmental factors leading to accidents. The combination of these factors would help to assure that the myriad uses of helicopters in the military as well as the civilian sector would be adequately represented in the data base.

Second, the Army experienced an average of 91 major accidents per year from fiscal years 1978-1982 and a substantial portion (75 percent) of these accidents were attributed to human error at an estimated average cost of $27.6 million per year.[4] This fairly large sample size would present a wide range of events for analysis. By reviewing a sufficiently large sample, it was felt that human error accident trends, if any, would become more readily evident.

---

[4]Reeder, M.J., Op. Cit., p. 1-1.

Third, the accident data base on civil helicopter accidents was not found by other investigators to contain information of sufficient detail to assess technology needs.

An ORI team worked on-site at the Fort Rucker facility for two weeks to analyze the events and technology implications of individual case records. During this period, the team reviewed 110 pilot error accident records randomly selected from available reports on Class A and Class B accidents. The review covered about 72 percent of the Class A and B mishaps attributed to pilot error for fiscal years 1981-1983. From those selected, 36 occurred in fiscal year 1981, 43 in 1982, and 30 in 1983. Sixty-seven percent were Class A and 33 percent were Class B accidents. As defined by the Army, Class A accidents are those that result in a fatality or permanent total disability to an individual, or total loss of an airframe, or property damage and injury costs which exceed $500,000. Class B accidents are those that result in hospitalization of 5 or more persons, or one or more permanent partial disabling injuries, or property damage and injury costs between $100,000 and $500,000. The total cost estimate of the 110 mishaps considered in the review was $62,630,494.

Review of the 110 case records at Fort Rucker focused initially on Accident Board findings and detailed descriptions of accident sequence of events. Examination of photographs of crash sites and post-crash conditions of helicopters was very useful in placing accident events in their proper and understandable perspective. Additional information derived from the mishap reports included type of accident, operating weight, mission, phase of operation, time of day (day, night, dusk), type of flight clearance, terrain conditions, pilot experience, type of accident events, and related materiel malfunctions.

A sample of the data forms used to guide data acquisition for the study is shown in the Appendix. The forms were derived from Department of the Army Pamphlet 385-95 on "Safety, Aircraft Accident Investigation and Reporting," with some modifications to omit sensitive information, such as specific references to persons, operational units, location, and date of individual events. To further safeguard the sensitive aspects of Army records, the ORI team assigned its own reference numbers to each modified data form, with traceability retained only by the U.S. Army Safety Center.

The modified data acquisition forms were used to assemble information in spreadsheet format for comparative analysis and aggregation of technology needs. The data forms for individual mishaps were then destroyed to further protect Army control over the source of the data.

III. DATA BASE ANALYSIS

All of the information derived from the mishap reports was analyzed to assess facts, conditions, and circumstances that could contribute to determining technology needs. The results of this data base analysis are discussed in this section of the report.

In considering the applicability of technology needs to civilian and military uses of helicopters, it is important to note that virtually all of the accidents reviewed involved flight operations with at least two crew members. The co-pilot, or in some cases an instructor pilot, was at least available to provide assistance in areas such as determining visual cues, monitoring instruments and avoiding obstacles. Such may not be the case in certain civilian applications where the entire workload may be vested with the pilot as the sole crew member.

Most (85 percent) of the mishaps occurred on flights operating under visual flight rules on local flight clearances; the other mishaps occurred on itinerant flights under visual flight rules. Weather conditions were determined to be a contributing factor by the investigative boards in less than 11 percent of the mishaps. A low rate of occurrence (16.7 percent) of post-crash fires was also noted, which may be attributed to extensive use of crashworthy fuel cells in Army aircraft.

Table 2 summarizes the mishaps by aircraft type, time of day (light conditions), and other significant circumstances or events pertinent to assessing technology needs. The distribution of mishaps by aircraft type appears to be primarily influenced by the composition of the Army helicopter fleet. Although low visibility conditions at night or dusk had an influence on some mishap events, most (76.4 percent) of the accidents occurred during daylight hours.

Over one-third of the mishaps involved circumstances or significant events summarized in the table. About 17 percent occurred during practice autorotations and simulated emergencies during pilot proficiency training flights. This suggests a potential need for using advanced flight simulators for flight proficiency training. In-flight equipment malfunctions led to improper pilot actions in 9 percent of the mishaps. Such events indicate a need for improvements in monitoring and diagnostic capabilities for flight-critical systems. In addition, those pilot errors (7.3 percent) resulting from unexpected instrument meteorological conditions (IMC) highlight a need to further improve the pilot's flight management capabilities by applying advanced technology in flight control and display systems.

TABLE 2

HELICOPTER ACCIDENTS BY AIRCRAFT TYPE, TIME OF DAY AND SIGNIFICANT EVENTS

Aircraft Type	Number of Mishaps	Time of Day			Significant Events			
		Day	Night	Dusk	Equipment Malfunctions	Simulated Emergencies (Power Loss)	Practice Autorotations	Inadvertent IMC
UH-1	44	34	9	1	4	2	7	3
OH-58	30	26	2	2	1	1	0	4
AH-1	19	12	7	0	2	1	5	1
CH-47	7	6	1	0	2	0	0	0
UH-60	4	2	2	0	0	1	0	0
OH-6	4	2	1	1	1	0	1	0
CH-54	1	1	0	0	0	1	0	0
TH-55	1	1	0	0	0	0	0	0
Totals	110	84	22	4	10	6	13	8

The distribution of mishaps by type of mission and pilot experience level in terms of rotary wing flying hours is shown in Table 3 below. The flight hours for the crew member directly involved in the human error causing the mishaps was used in this analysis. The lowest experience level (0-200) group is considered to be in a "school environment" where their actions are closely monitored and supervised. Conversely, those pilots with over 1,500 hours rotary wing time tend to be the pilots in command and/or instructor pilots. The distribution of mishaps in Table 3 by type of mission and pilot time probably reflects flight time exposure, but specific data for investigating that type of correlation was not available for analysis. A study by NTSB of civil rotorcraft accidents shows that as many as two-thirds of the pilots involved in civil rotorcraft accidents were flying in a professional capacity.[5] Such statistics indicate that flight experience and pilot qualifications do not provide an adequate means in themselves for eliminating human error as a cause factor in rotorcraft accidents.

TABLE 3

HELICOPTER ACCIDENTS BY TYPE OF MISSION AND PILOT TIME

Type of Mission	Pilot Time in Hours							Summation of Mishaps
	0-200	201-500	501-1000	1001-1500	1501-2000	2001-3000	Over 3000	
Flt. Proficiency Training	5	6	10	4	2	6	6	39
Tactical Training	0	15	5	2	2	2	1	27
Service	0	11	15	0	2	3	4	35
Maintenance Checks	0	1	1	1	0	1	1	5
Search and Rescue	0	0	1	1	0	2	0	4
Summation of Mishaps	5	33	32	8	6	14	12	110

[5] NTSB Special Study, Op. Cit., p. 15.

As shown in Table 4, over half of the mishaps involved collisions with obstacles (29 percent) and collisions with ground (27 percent), which includes hard contact at termination of an autorotation and powered landing. This indicates that human vision may be inadequate for detecting obstacles to safe flight and determining closure rates with the ground. The relative high level of mishaps occurring during low level flight, hover operations and autorotations further indicate that the human operator needs assistance to safely control helicopter operations near the ground.

TABLE 4

HELICOPTER ACCIDENTS BY ACCIDENT TYPE AND PHASE OF OPERATION

	Phase of Operation													
Accident Type	Stationary Turning	Ground Taxi	Hover IGE (Incl. Air Taxi)	NOE Deceleration	Hover OGE	Takeoff	Climb	Low Level Flight	Cruise	Powered Descent	Approach	Auto-rotation	Landing	Totals
Roll Over	1		3			4						3	2	13
Collision With														
Aircraft In Air							1		1					2
Aircraft On Ground			2										1	3
Collision With														
Ground		1	3	1			3	1	3	2	5	8	3	30
Water								1				1		2
Collision With Obstacles:														
Wires			1				1	4	1			2		9
Poles		2												2
Trees			5			1		6			1	2	1	18
Others (fence, rocks, etc.)			1							2	1	1		3
Rotor Strike on Fuselage		1	1									3	4	9
Loss Tail Rotor Effectiveness			1		3	1		5	6		3			19
Total Mishaps	1	4	17	1	3	6	5	17	11	4	10	20	11	110

This brief analysis of Army helicopter accidents indicates several areas in which technology can be applied to reduce human error as a contributing cause of helicopter accidents. Specifically, these areas include advanced flight control and display systems, advanced monitoring and diagnostic systems, and advanced flight simulators for flight proficiency training. Evidence indicates that too much dependence may have been placed upon the human pilot to perform a complex set of functions in order to fully exploit the unique operational capabilities of the helicopter. The first two technology needs, if integrated into the vehicle design with adequate man-machine interfaces, could improve the pilot's flight management capabilities to handle necessary human tasks in critical flight situations. Advance flight simulators could be used to achieve and maintain flight proficiency skill levels while reducing the risk of damage to the aircraft and, importantly, reducing associated injuries and fatalities without damaging perfectly good aircraft which can be used for other missions.

The analysis of accident statistics and data on pilots, aircraft and the operating environment provides a macro approach for assessing factors affecting aircraft safety. In order to provide more insight into the circumstances and events which led to each mishap, ORI selected a task element analytical approach. This approach involved review of the accident records on a case-by-case basis to examine the human task errors and sequence of events for each mishap. This methodology permitted the analyst to assess the nature of the problems which need to be resolved and applicable technology implications.

IV. ASSESSMENT OF TECHNOLOGY NEEDS

In the review of Army accident records, ORI assessed the technology implications of each mishap by considering what happened, the sequence of events which caused the accident to happen, and the human tasks involved in these events. For example, an investigative board determined that an experienced pilot, while executing a practice autorotation under dusk light conditions, erred by pulling the collective pitch at an altitude that was too high during deceleration, resulting in a hard landing and main rotor blade strikes on the tail boom, which caused major aircraft damage. The standard visual autorotation recovery technique depends on visual cues and depth perception judgments of the pilot, aided by visual instrument scans (i.e., airspeed, rate of descent, altimeter indicators) to make a successful landing. Thus, this type of mishap (hard landings from a practice autorotation) suggests two types of technology needs -- the use of advanced flight simulators for practicing emergency procedures, and application of advanced flight control and display technology to aid the pilot in performing aircraft control functions in emergency as well as normal operating situations.

This example illustrates the task element analytical approach used by ORI on a case-by-case basis to assess areas in which technology could be applied to reduce or eliminate human error related accidents. For 5 of the mishaps (4.5 percent of the records reviewed), no apparent technology could be identified as relevant to those specific sequence of events. One or more technology needs were identified for each of the other 105 mishaps. The technology needs for each mishap were classified as primary and secondary to facilitate grouping the mishaps by technology needs. The need was classed as primary if the sequence of events indicated that the application of an advanced technology to meet that need would most likely have prevented the mishap. Application of advanced technology to meet secondary needs could also help to prevent the accident and may be synergetic with the primary need.

The technology needs identified from review of the sequence of events for each of the mishaps are aggregated into seven groups. These are:

1. No apparent technology implications. The sequence of events leading to the mishap occurred in such a way that no apparent applications of advanced technology could reasonably be identified for a pilot-controlled aircraft.

2. Vehicle design alternatives for eliminating the tail rotor.

3. Advanced flight simulators for pilot proficiency training.

4. Advanced flight control and display systems to reduce pilot workload for aircraft control.

5. Obstruction detection devices to enhance human capability and reduce or eliminate dependence on human vision for detection, identification, and determination of distance.

6. Automated monitoring and diagnostic systems to aid the pilot in monitoring flight-critical systems, reduce cockpit instrument scan, and provide diagnostic information on conditions affecting aircraft performance (e.g., power required versus power available, trends in engine parameters, impending failure/malfunction warning, etc.).

7. Contingency power capabilities for short use in situations where exceptional power demands required to save the aircraft exceed the rated power available.

The aggregation of mishaps into these seven groups is discussed below.

NO APPARENT TECHNOLOGY IMPLICATIONS

Summary of Mishaps

Number:	5 mishaps (4.5 % of sample)	Aircraft:	AH-1S	(1 mishap)
			CH-47C	(2 mishaps)
			UH-1H	(1 mishap)
Injuries:	No fatalities, 15 nonfatal.		UH-60A	(1 mishap)
Cost Estimate:	$5,328,440 (9.3% of sample)			

There does not appear to be any feasible advances in new technology for alleviating the human error aspects in the events involved in five mishaps reviewed during the study. Two of these mishaps involved aircraft damage resulting from pilot actions during ground taxi: in one, the Board found that excess taxi speed resulted in loss of directional control and then actions by the pilot to regain control resulted in a fuselage strike by the rotor blades; in the other, the pilot determined that the aircraft had an "out-of-rig" cyclic condition which caused the aft part of the fuselage to become airborne. Pilot control reaction then resulted in fuselage impacting with the ground with sufficient force to cause damage.

The other three mishaps involved loss of aircraft control during steep turns at low altitudes when the pilots attempted to execute flight maneuvers that exceeded the design performance limits of the aircraft. While control limiting devices could possibly be used in the aircraft design to preclude these types of pilot errors, such a design approach would probably place unacceptable design constraints on aircraft maneuverability.

ALTERNATIVES TO THE TAIL ROTOR

Summary of Mishaps

Number:	6 mishaps (5.5% of sample)	Aircraft:	OH-58A (3 mishaps) UH-1H (1 mishap) UH-1V (2 mishaps)
Injuries:	No fatalities, 8 nonfatal		
Cost Estimate:	$1,768,799 (2.8% of sample)		

The common thread of the six accidents summarized above is that the initial events in the accident sequences probably would not have led to an actual Class A or B accident but for a secondary tail rotor strike. In one case, an improperly secured flight jacket left the cabin and struck the tail rotor system, resulting in loss of both rotor blades and the gearbox. Another accident involved the separation of an engine cowling with similar consequences. The initial causal event for two other accidents involved abrupt flight actions which led to tail rotor damage. In one, the aircraft was brought to a quick stop in a nose-high attitude, causing the main rotor blades to sever the tail rotor drive shaft. In the other, an abrupt deceleration led to a ground strike by the tail rotor. The remaining two accidents involved a tail rotor tree strike while flying too low and a ground strike as a helicopter pitched fore and aft during a rearward taxi at a crowded flight pad.

Assessment of Technology Implications

The vulnerability of the tail rotor to damage from tail rotor strikes with the ground, trees, parked aircraft, and objects departing the aircraft during flight is a common design characteristic of the mishaps summarized above, as well as several mishaps included under other technology areas. This suggests a technology need for seeking alternatives to the use of an exposed tail rotor for directional control in single rotor helicopter designs.

Types of New Technology Needs

There is a technology need to develop acceptable alternatives to the use of exposed tail rotors in helicopter system designs. Advance concept formulation and proof-of-concept research is required to investigate alternative methods for yaw control for eliminating the hazards of a tail rotor. Current state-of-the-art approaches include the Bell Ring Guard, the Aerospatiale fenestron type ducted fan, the Hughes NOTAR concept, coaxial main rotors, tandem rotors and tilt rotors. While these approaches are used in specific aircraft designs, the conventional single rotor helicopter with an exposed tail rotor continues as the design approach selected for most rotorcraft.

Rationale for New Technology

The tail rotor is commonly used with single rotor helicopter designs to provide directional control. Although useful for such applications, exposed tail rotors can be a hazard to personnel walking near the aircraft on the ground and vulnerable to damage by contact with solid objects. Damage to the tail rotor seriously degrades flight control. The Public Service Helicopter Users Workshop in July 1980 at the NASA Ames Research Center identified the elimination of the tail rotor as a vehicle design technology need to enhance safety.

ADVANCED FLIGHT SIMULATORS

Summary of Mishaps

Number:	21 mishaps (19.3% of sample)	Aircraft:	AH-1S	(4 mishaps)
			TAH-1S	(2 mishaps)
			CH54A	(1 mishap)
Injuries:	5 fatal, 17 nonfatal.		JOH-6A	(1 mishap)
			OH-58A	(1 mishap)
Cost Estimate:	$13,216,408 (21.1% of sample)		TH-55A	(1 mishap)
			UH-1H	(10 mishaps)
			UH-60A	(1 mishap)

All of the mishaps included in this technology need grouping occurred during practice autorotations (13 mishaps), simulated in-flight emergencies (6 mishaps), or other pilot proficiency training events. The autorotation related mishaps covered a range of circumstances. In some, the pilot seemed to have known the proper procedure to follow, but erred in improperly executing the maneuver. For example, collective pitch was pulled at too high or too low an altitude, or the aircraft was not placed in the proper alignment prior to touchdown. The results were hard or uneven ground impacts and resultant damage. Other mishaps involved improper choice of pilot control responses or being in a state of confusion when confronted with a short response time simulated emergency. Here, the instructor pilot either gained control of the aircraft too late or simply could not gain sufficient control to prevent damage. Another set of circumstances involved misjudgment of visual cues. This typically occurred in night or dusk operations as depth perception became distorted and the pilot was unable to adequately judge aircraft altitude.

Intervening malfunction/failures in two instances transformed the simulated emergencies into actual mishaps. One instance involved loss of power from a second engine while practicing single engine emergency procedures. In the other, the engine did not respond to pilot recovery actions during a simulated engine failure over treed terrain.

In other mishaps, the pilots erred more in the selection of location for practicing simulated emergencies than in emergency responses. For example, one mishap occurred while performing a simulated engine failure in a confined area, which complicated events into an unsuccessful recovery. Another mishap occurred when the toe of the helicopter skid impacted soggy lumps of sod in a grassy landing area.

The other two mishaps grouped in this technology needs area were attributed to pilots with limited flight experience improperly performing pilot proficiency training events.

Assessment of Technology Implications

Helicopter simulators with visual terrain references offer potential alternatives to using aircraft for flight proficiency and basic pilot training.

Types of New Technology Needs

Develop the necessary systems technology to facilitate development and use of practical, cost-effective helicopter simulators for pilot training in flight procedures, techniques and responses to emergencies. A helicopter simulation conference sponsored by the FAA in April 1984 identified many technical problems in high-fidelity simulation that can be divided into two primary simulator functional areas: motion and vision.[6] Another problem area involves the acquisition of accurate data concerning the flight characteristics of helicopters. A related technology need includes human factors research into the cost-effectiveness of using simulators to replace aircraft for pilot training in emergency procedures and basic pilot skills, as well as instrument flight procedures. Another related technology need includes advances in flight information displays to eliminate or reduce pilot dependence on visual cues to accomplish autorotation landings.

Rationale for New Technology

Helicopter simulators can provide a potential alternative to using aircraft for pilot proficiency training. Advantages in using simulators include:

a. Pilot errors made while learning basic skills and maintaining proficiency in emergency procedures do not result in aircraft and property damage or personnel casualties.

b. Available aircraft time can be devoted to operational use.

---

[6]Jensen, David, "The FAA's Simulator Conference in Atlanta," Rotorcraft & Wing International, July 1984, p. 42.

Summary of Mishaps

Number:	25 mishaps (22.9% of sample)	Aircraft:	AH-1S	(4 mishaps)
			FAH-1S	(2 mishaps)
			AH-1G	(1 mishap)
Injuries:	8 fatal, 23 nonfatal.		OH-6A	(1 mishap)
			OH-58A	(7 mishaps)
Cost Estimate:	$15,394,824 (24.6% of sample)		UH-1H	(8 mishaps)
			UH-1M	(1 mishap)
			UH-60A	(1 mishap)

Most of the 25 mishaps grouped in this technology needs area involved some combination of adverse environmental condition (fog, dust, snow, etc.) or terrain (slope, mountain) condition, and divided attention caused by the adverse condition or preoccupation with some mission function (e.g., communications, etc.). The mishaps then occurred as pilots became disoriented or simply were unaware that their aircraft changed from the perceived flight conditions. The unnoticed drifting and/or descents led to impact with the ground or an obstacle.

An understanding of the technology implications of these mishaps can best be characterized through selected synopses of the accident sequences, as follows:

- Pilot experienced loss of spatial orientation during night flight under poor visibility conditions. The aircraft was inadvertently placed in an unrecovered descending turn.
- A change in aircraft stability occurred as the pilot conducted a system check on the ground in a high wind condition. The aircraft became light on its skids and rolled.
- Visual references were lost during hover due to blowing snow. Aircraft drift was unnoticed, leading to a tree strike.
- During landing approach, pilot flew into a dust cloud and encountered a partial brown-out condition. As pilot attempted to maintain hover position, the aircraft went into an undetected drift and struck a tree.
- During attempted takeoff from a slope, pilot failed to level the aircraft properly, resulting in dynamic roll. Pilot concentration was divided, due to concern over nearby obstacle avoidance.

- Pilot made compensatory control inputs during flight for an extended period with extra weight of a passenger and accompanying equipment. When the passenger was discharged, pilot did not readjust his controls, resulting in aircraft roll on takeoff.

- Pilot was preoccupied with other mission responsibilities during hover and did not recognize that aircraft was in a rearward, descending drift. In monitoring instruments, pilot was aware of altitude above the ground but not tree clearance.

Assessment of Technology Implications

It appears that the effects of errors involving pilot functions and workload can be reduced by improvements in the capabilities of the flight control system and display of flight management information. System designs which require continuous inputs by the pilot to maintain stable flight place significant flight control workload demands on the pilot. These demands can impact on flight safety when human errors occur because of spatial disorientation, distractions in concentration, impulsive control movements, inadequate communications/information, misjudgments and improper decisions. The extent to which advances in technology for flight control systems can reduce pilot workload and the effects of human error is a consideration for enhancing flight safety.

Types of New Technology Needs

There are apparent needs to assist the pilot in performing flight control functions in the complete flight profile of the aircraft, including cruise, hover, taxi, climb, descent, landing and takeoff; particularly for operations in remote areas under obscured vision flight conditions. These needs involve advances in technology for advanced flight displays and automatic flight stability. Flight displays should be developed that provide integrated information necessary for the particular tasks to be performed during the various phases of flight. The advanced flight control system should be developed such that a rotorcraft will continue to operate in stable controlled flight, including hover and other modes as selected by the pilot, in an automatic "hands-off" control condition, unless maneuver changes are introduced by pilot inputs, flight profile programs, or sensor systems. Advance flight control and display system needs include new technology to accomplish safe operations under reduced vision flight conditions for all phases of operations and to provide information on aircraft position, altitude, attitude, heading, airspeed, track and ground speed, and flight path obstructions to safe flight. These technology needs are perceived as flight management aids for the human pilot who still has a major role in the overall flight mission.

Rationale for New Technology

Advances in automated flight stabilization systems can reduce pilot workload and human errors. By relieving pilots of the need to perform continuous stability control functions, they can focus attention on flight management and decision-making functions. The review of accident records in this analysis, as well as public service helicopter user experiences (i.e., Public

Service Helicopter Users Workshop in July 1980)[7] indicate needs for advances in control concepts, all-weather capability, multi-functional displays, precision location/navigation, and capabilities to operate in remote areas under restricted visibility conditions, including landings on sloping, uneven terrain.

OBSTRUCTION DETECTION

Summary of Mishaps

Number:	20 mishaps (18.3% of sample)	Aircraft:	AH-1S	(2 mishaps)
			CH-47C	(2 mishaps)
			CH-47C	(1 mishap)
Injuries:	13 fatal, 42 nonfatal.		OH-6A	(1 mishap)
			OH-58A	(4 mishaps)
Cost Estimate:	$11,952,376 (19.1% of sample)		OH-58C	(1 mishap)
			UH-1H	(7 mishaps)
			UH-1V	(1 mishap)
			UH-60A	(1 mishap)

The mishaps relating to obstruction detection capabilities can be aggregated into three types of events. These are:

a. The aircraft hit an undetected obstruction during low level flight. Twelve (12) of the above summarized mishaps involved this type of situation. Six (6) of these events involved wire strikes. Four (4) involved contact with objects, such as trees or rocks, which the pilot did not see or misjudged clearance distance. The other two (2) mishaps involved striking an object (fence and parked aircraft) on final approach during a low visibility landing.

b. During ground taxi or hover operations in congested areas, the pilot did not see or misjudged clearance distance to an obstruction (pole, wires, parked aircraft) that was struck by main or tail rotor blades (4 mishaps). In one instance, although another crew member was monitoring clearance, there was miscommunication between the pilot and guide. A somewhat similar situation involved a crew member guide for a ground taxi performing his function inside the aircraft and passing on improper information due to his misjudgment of distances. A third mishap occurred during a hover taxi from a crowded ramp. Here, a crew member was monitoring clearances and was aware that the rotor tip was closing on another aircraft, yet failed to inform

[7]Helicopter Technology Needs, Public Service Helicopter User's Workshop, NASA Ames Research Center, July 14-16, 1980, Volume I - Summary, Volume II - Appendices.

the pilot of this fact. (Stress was cited by the Board as a probable contributing factor.)

c. In mid-air collisions (2 mishaps), the pilot lost visual contact with another aircraft in a station keeping situation or did not detect a nearby aircraft soon enough to prevent collision.

Assessment of Technology Implications

a. The technology implications for the mishaps involving undetected obstructions pose a need for medium-range (probably less than two miles) obstruction detection devices that can inform the pilot of the existence and relative position of hazards to safe flight. Existing limitations of NVG (night vision goggles) now being widely used for operations at night in some mission areas indicate a need for further development of advanced technology in night vision enhancements.

b. The mishaps involving taxi or hover operations indicate a need for a short-range obstruction warning system that the pilot can use to determine safe rotor clearance. Such a system could possibly be set for clearance distances selected by the pilot to issue a warning if rotor clearance decreased below the selected threshold.

c. Mid-air collision mishaps indicate a need to detect the existence and closure rate of other aircraft in the air.

Types of New Technology Needs

a. Develop advance technology in flight path situation displays and airborne sensors for detecting obstructions to safe low altitude flight. The airborne sensors should be capable of detecting such obstructions as power lines, TV towers and wire supports, buildings, trees, and uneven terrain profiles at sufficient range for safe aircraft flight path direction, either through an integrated advanced flight control system or pilot-operated controls. Also, further improvements in NVG capabilities are needed to enhance the pilot's night vision to perform cockpit functions, as well as see outside the cockpit.

b. A method, other than human visual estimates, to alert the pilot that rotor clearance to nearby obstructions is less than the required clearance margin for maneuvering during hover or ground taxi operations in congested areas.

c. A method, other than human visual detection, for airborne collision avoidance and station keeping. The need for an airborne collision warning and avoidance system is to alert pilots of a collision threat and flight maneuvers required to avoid collision. The technology need for station keeping is to assist the pilot in maintaining a safe separation distance during formation flight. (This technology need is similar to that identified above in paragraph b.) There is a need to investigate the use of airborne collision avoidance equipment applications in helicopter operations for such functions as station keeping, rendezvous, traffic control and collision avoidance, and precise time command and control functions.

Rationale for New Technology

In order to exploit the unique capabilities of the helicopter, there are both civil and military mission needs for conducting flight operations at low altitudes which increases the threat of collision with undetected obstructions and adds to the pilot workload. Examples of civil missions include police surveillance, fire fighting, agricultural applications, emergency medical services, and search and rescue. Military flights may use the terrain environment (trees, gullies, etc.) to mask the presence of combat helicopters from opposing forces. Such operations are often carried out in remote areas. However, helicopter rotors are susceptible to severe damage from striking obstructions on the ground as well as during flight. In addition, the burden placed on the pilot for visual detection of obstructions to safe flight and human depth perception for determining suitable clearance for a large diameter rotor while performing other tasks adds to the complexity of achieving safe helicopter operations. Therefore, the further application of new technology which can reduce pilot workload and increase the margin for errors in human performance should enhance flight safety in performing helicopter missions.

AUTOMATED MONITORING AND DIAGNOSTIC SYSTEMS

Summary of Mishaps

Number:	29 mishaps (26.6% of sample)	Aircraft:	AH-1S	(3 mishaps)
			CH-47C	(2 mishaps)
			OH-6A	(1 mishap)
Injuries:	7 fatal. 41 nonfatal.		JOH-58A	(1 mishap)
			OH-58A	(13 mishaps)
Cost Estimate:	$12,022,725 (19.2% of sample)		UH-1H	(8 mishaps)
			UH-1V	(1 mishap)

Review of helicopter accidents indicates that the mishaps in this technology need area can be grouped as follows:

a. Sequences of events involving actual or suspected in-flight materiel failures in which the pilot (or crew) misinterpreted or did not accurately diagnose the cause-and-effect relationships of a problem (i.e., source of noise, smoke, vibrations, tachometer fluctuations, etc.). For example, a materiel failure in an engine transmission caused a fire, seizing of transmission and ultimate loss of engine power. The crew, however, misinterpreted the problem, thinking it was an engine fire, and shut down the unaffected engine, resulting in autorotation due to total loss of power. Another instance during a ground control approach involved an RPM warning light going on, which the crew misinterpreted as a complete engine failure. The aircraft was placed into autorotation to land in water. A third instance involved an aircraft which began to lurch. When an instrument scan revealed nothing abnormal, the pilot assumed the source of the problem was a failure of the main transmission mount. The actual problem was a failure of the Stabilization Control Augmentation System (SCAS).

b. Diversion of pilot attention between cockpit monitoring of flight instruments and other workload functions (e.g., terrain/obstacle clearance, lookout, equipment/system checks, weapons use, etc.).

c. Operations near or exceeding the operational performance limits of the aircraft in which the pilot is unaware of the status of critical flight parameters or changes in conditions affecting these parameters (e.g., relative wind, loss of translational lift, power available, etc.). Several mishaps in this grouping involved loss of tail rotor effectiveness, particularly in OH-58A aircraft (12 incidents), and inability to maintain main rotor RPM in marginal performance conditions (5 mishaps). The loss of tail rotor effectiveness typically involved reduction in forward airspeed in a tail wind condition. The aircraft then went into uncommanded right turns as anti-torque control was lost.

Assessment of Technology Implications

The mishaps addressed in this section indicate a need for improvements in technology to assist the pilot in monitoring the performance of flight-critical systems, reduce pilot needs for continuous scanning of cockpit instruments, and provide diagnostic information on equipment performance and conditions affecting aircraft performance. Dependence on the use of manual techniques for aircraft performance planning, coordinated performance of complex flight and mission functions, and reliable diagnosis of in-flight materiel failures appear to be inadequate for helicopter system designs.

Types of New Technology Needs

Provide advanced technology in automated system monitoring and diagnostic information on flight-critical systems and aircraft performance. The integration of this technology into helicopter system designs should provide:

a. Monitoring of the status and trends in flight-critical systems without requiring the pilot to continually scan cockpit instruments;

b. Warning of adverse trends and impending system failures;

c. Correlated information on malfunctions in flight-critical systems; and

d. An automated diagnostic system for predicting and monitoring aircraft performance capabilities and power demands to assist the pilot in operating the aircraft within its performance limitations.

Rationale for New Technology

Review of helicopter accidents indicates that an automatic aircraft performance and limitation monitor is needed as an in-flight system to improve the safety margin for missions involving near-limit aircraft operations.

Furthermore, public service helicopter users expressed a similar technology need at a July 1980 workshop at the NASA Ames Research Center. In addition, such a system can reduce human error in diagnosing cause and effect relationships. Sources of unusual sounds and vibrations are sometimes misinterpreted. Warning lights, while useful, indicate only that a problem may exist. Such situations can lead to accidents that could have been avoided if the flight crew had been provided better diagnostic information. Currently, information on system status is presented to the pilot in "raw data" format that requires time-consuming pilot interpretation.

CONTINGENCY POWER

Summary of Mishaps

Number:	4 mishaps (3.6 % of sample)	Aircraft:	UH-1H UH-1V	(3 mishaps) (1 mishap)
Injuries:	No fatalities, 9 nonfatal.			
Cost Estimate:	$2,446,922 (3.9% of sample)			

The four mishaps included in this technology grouping all occurred during operations in mountainous terrain. One case involved an aircraft clearing a mountain ridge and then encountering another ridge. The pilot initiated a climb, but the aircraft exceeded maximum torque, resulting in RPM bleed and loss of effective control. A second case involved a search and rescue mission along a mountain canyon. As the terrain rose rapidly in front of the aircraft, the pilot allowed forward airspeed to decrease to zero. Engine RPM began to bleed and the aircraft began uncommanded right turns. Effective control was lost and the aircraft crashed. Similar sequences of events were encountered in the other two mishaps.

Assessment of Technology Implications

The mishaps included in this category of technology needs involved events in which the margin of power available was small and the pilot encountered a flight situation in which power requirements exceeded power available. The events tended to result from inadvertent loss of translational lift in out-of-ground effect situations at or near maximum aircraft performance. A relevant technology need for such incidents is to provide a contingency power source(s) of limited duration which the pilot can select in emergency situations to save the aircraft. In addition to the four mishaps noted above, a contingency power capability could possibly have prevented five of the accidents included in the technology area for "Automated Monitoring and Diagnostic Systems." Those five mishaps were included under a different grouping because the sequence of events indicated that the pilot did not know that the aircraft was operating at or near the limits of available power. For example, an aircraft was loaded in excess of its allowable gross weight, but the pilot was unaware of this fact. The pilot accordingly miscalculated the amount of torque available. The pilot's approach in mountainous terrain became shallow, resulting in an out of ground effect (OGE) hover, which the aircraft could not maintain in its over gross weight condition.

Types of New Technology Needs

Develop engine technology and/or other contingency power sources for helicopters that can be activated by the pilot for short-duration emergency use, even though that event may require follow-up inspections, servicing or an engine change. The objective of using contingency power is to save the aircraft.

Rationale for New Technology

The unique capabilities of the helicopter to perform such missions as search and rescue in remote mountainous terrain contributes to its use in operations near the limits of available power. Under such conditions, the safety margin for errors in pilot techniques or capabilities to respond to in-flight emergencies (i.e., partial power loss) is small. In those situations, a source of additional power for even a limited time period could improve aircraft safety. The Public Service Helicopter User Workshop in July 1980 at the NASA Ames Research Center identified emergency power capabilities as a technology need for helicopters used for public service.

MEETING THE TECHNOLOGY NEEDS

Constant improvements in technology have provided the knowledge base required for growth in rotorcraft. The preceding discussions in this section of the report have highlighted needs for advanced technology which, if applied, could reduce or eliminate human error as a cause factor in helicopter accidents. Such benefits, of course, could be a stimulus for further growth, if the costs are acceptable to helicopter users. The potential cost impacts of improvements in technoloy must be assessed with due regard for accident costs.

It is recognized that product improvements are being made by incorporating technology currently available which can meet in various aspects some of the needs identified in this study. Examples of current technology applications included:

- Multi-function displays;
- Electronic flight instrument systems;
- Digital automatic flight control systems with three-axis stability augmentation;
- Automatic navigation management systems;
- Doppler track and ground speed measurements;
- Improved altimeters (i.e., radar and encoding altimeters); and
- Crew training simulators (i.e., UH-1H flight simulators, AH-64 Combat Mission Simulators, etc.).

While product improvements offer potential for improving some aspects of problems involved in pilot errors, it is apparent that existing technology cannot resolve the full scope of identified technology needs. The next section will compare these needs to ongoing and planned research and technology activities to determine areas where new technology thrusts may be required.

V. AREAS FOR NEW TECHNOLOGY

Table 5 presents a comparison of the technology needs discussed in the preceding section with related rotorcraft technology program activities of NASA, the military services, and the Federal Aviation Administration (FAA). The synopses of ongoing and planned research and technology (R&T) activities are based on a review of the 1983 ORI study comparing rotorcraft technology programs covered in the NASA Aeronautics Program, the DoD Technology Base and Advanced Technology budget activities, and the R&D activities of the FAA Rotorcraft Master Plan.[8] Organization as well as programmatic relationships were considered in that comparative analysis of rotorcraft projects. Therefore, the joint NASA/Army program activities at collocated Army laboratories and NASA research centers are listed under the "Integrated NASA/Army" heading. There are other NASA and Army programmatic activities which were not included under the integrated project activities. These efforts were included under "Other NASA Projects" and "Other DoD Projects," as applicable.

The comparison of technology needs identified in Section IV with the focus of related ongoing rotorcraft R&T activities provides a basis for determining where new technology thrusts could benefit the further reduction or elimination of pilot error related accidents. The focus of these new initiatives is presented in Table 5 under "Proposed Areas for New Technology Activities."

---

[8] Kirkland, J. T. and Simpson, W. E., Rotorcraft Research and Technology Program Integration - 1983, TR No. 2207, Prepared under contract for the National Aeronautics and Space Administration, Washington, D.C., July 1983.

TABLE 5

COMPARISON OF NEW TECHNOLOGY NEEDS AND RELATED PROJECT ACTIVITIES

IDENTIFIED TECHNOLOGY NEEDS TO REDUCE ROTORCRAFT ACCIDENTS	RELATED ONGOING AND PLANNED RESEARCH AND TECHNOLOGY ACTIVITIES				PROPOSED AREAS FOR NEW TECHNOLOGY ACTIVITIES
	INTEGRATED NASA/ARMY	OTHER NASA PROJECTS	OTHER DOD PROJECTS	FAA PROJECTS	
1. Vehicle Design Alternatives to the Tail Rotor • Develop acceptable alternatives to the use of exposed tail rotors (also a PSH Vehicle Design Technology Need).			Army 6.22.09A/AH76A • Develop practical alternatives for the tail rotor for directional control (including NOTAR). Army 6.22.09A/AH76G • Systematic assessment of new technology developments on the next generation family of light helicopters, as well as future pre-planned product improvements. • Design studies and sustainability tradeoffs for significant new aviation programs. Army 6.22.20A/D325 • Conduct technology integration for next generation LHX.		1. Investigate advanced concepts to provide alternative design configurations for military and civil users.
2. Advanced Flight Simulators • Develop system technology to facilitate use of practical, cost-effective helicopter simulators for pilot training in flight procedures, technique and responses to emergencies.			Navy 6.27.57N/F57-52b • Evaluate suitability of candidate simulator systems to incorporate in a helicopter training device.		2. Investigate the feasibility of using flight simulators as a practical, cost-effective alternative to using aircraft to acquire and maintain pilot skills for responding to power failures and executing autorotations.

TABLE 5 (continued)

IDENTIFIED TECHNOLOGY NEEDS TO REDUCE ROTORCRAFT ACCIDENTS	RELATED ONGOING AND PLANNED RESEARCH AND TECHNOLOGY ACTIVITIES: INTEGRATED NASA/ARMY	OTHER NASA PROJECTS	OTHER DOD PROJECTS	FAA PROJECTS	PROPOSED AREAS FOR NEW TECHNOLOGY ACTIVITIES
3. Advanced Flight Controls • Develop technology to assist the pilot in performing flight control functions in the complete flight profile of the aircraft, particularly for flight operations in remote areas under obscured flight conditions. (PSH user stated needs for advances in control concepts, all-weather capability, multi-functional displays, precision location/navigation, and capabilities to operate in remote areas under restricted visibility conditions, includings landings on sloping, uneven terrain. PSH need includes on-board wind shear, down draft detection system for SAR missions near cliffs.)	NASA 505-42-11 Army 6.22.09A/AH76M • Develop control system design criteria. • Develop control systems and display concepts for special conditions and missions. • Conduct studies of helicopter pilot information needs and natural sensory mechanisms for aircraft control. NASA 532-06-11 Army 6.32/16A/DB34 • Investigate controls and display concepts for helicopters carrying single- and multiple-point attached sling pods. NASA 505-42-11 Army 6.22.09A/AH76K,M • Research in man-machine integration technology to reduce pilot workload and/or improve performance.	NASA-532-01-11 • Joint NASA/FAA investigations of remote site guidance concepts using on-board radar and alternative configurations of NAVSTAR GPS. • Modify an existing general aviation G&C system and test in a simulated rotorcraft environment. Compare results with a contemporary rotorcraft guidance system for use in planning research to develop criteria for rotorcraft all-weather crew station design.	Army 6.32.11A/D315 • Develop and evaluate an Advanced Digital Optical Control System (ADOCS).		3. Advanced Flight Controls • Develop and evaluate control system concepts to provide automatic flight stability such that a rotorcraft will continue to operate in stable controlled flight, including hover and other modes as selected by the pilot, in an automatic "hands-off" control condition, unless maneuver changes are introduced by pilot inputs, flight profiles programs, or sensor systems. • Develop control systems and display concepts to accomplish safe operations under reduced vision flight conditions for all phases of flight conditions, including autorotations, and provide the pilot with continuous flight management information on aircraft track and ground speed, position, altitude, heading, airspeed, track and ground speed, and flight path obstructions.

TABLE 5 (continued)

IDENTIFIED TECHNOLOGY NEEDS TO REDUCE ROTORCRAFT ACCIDENTS	RELATED ONGOING AND PLANNED RESEARCH AND TECHNOLOGY ACTIVITIES				PROPOSED AREAS FOR NEW TECHNOLOGY ACTIVITIES
	INTEGRATED NASA/ARMY	OTHER NASA PROJECTS	OTHER DOD PROJECTS	FAA PROJECTS	
4. Obstruction Detection • Airborne sensors for detecting obstructions to safe low altitude flight within two miles. • Technology in flight path situation displays for low level flight path management to clear obstruction to flight. • Improvements in NVG capabilities to enhance pilot's capabilities to perform cockpit functions, as well as see outside the cockpit. • Technology to alert the pilot that rotor clearance (matter of feet) to nearby obstructions is less than the desired clearance margin (selected by the pilot) for maneuvering during hover or ground taxi operations in congested areas. • Airborne collision avoidance and station keeping.	NASA 532-06-11 Army 6.32.116A/DB34 • Conduct analysis and simulations to define pilot information needs for remote area operations.			FAA DL-50 • Survey user needs and preferences for Traffic Alert and Collision Avoidance System (TCAS). • Studies of surveillance and logic techniques for rotorcraft use of TCAS. • Flight tests to evaluate possible needs for special TCAS provisions for rotorcraft. FA DL-120 • Systems evaluation and tradeoff analysis of obstruction avoidance methods to improve the safety of rotorcraft operations at low altitudes. • Preparation of guidance material to support systems certification process.	4. Obstruction Detection • Investigate concepts for practical airborne sensors capable of detecting such obstructions to low level flight as power lines, TV towers, and wire supports, buildings, tall trees, and uneven terrain profiles at sufficient range (probably up to two miles) for safe aircraft flight • Develop and evaluate methods to determine rotor clearance to nearby obstructions (probably up to one rotor diameter) to provide pilot with a means other than human visual estimates of rotor clearance for maneuvering during hover or ground taxi operations in congested areas. The same method may be useful for station keeping in flight. • Investigate the use of airborne collision avoidance applications in rotorcraft for such functions as station keeping, rendezvous, traffic control and collision avoidance, and precise time command and control functions.

TABLE 5 (continued)

IDENTIFIED TECHNOLOGY NEEDS TO REDUCE ROTORCRAFT ACCIDENTS	RELATED ONGOING AND PLANNED RESEARCH AND TECHNOLOGY ACTIVITIES				PROPOSED AREAS FOR NEW TECHNOLOGY ACTIVITIES
	INTEGRATED NASA/ARMY	OTHER NASA PROJECTS	OTHER DOD PROJECTS	FAA PROJECTS	
5. Automated Monitoring and Diagnostic Systems • Computerized monitoring and trend warning system for flight-critical systems that does not require pilot scan of cockpit instruments. • Correlate information on in-flight malfunctions in flight-critical systems. • Automated diagnostic system for predicting and monitoring aircraft performance limits. (PSH user needs include performance limitation monitor, head-up display for warning and diagnostic information, aural warning system, on-line monitoring of engine conditions.)			Army 6.2209A/AH76D • Investigate methods for improving operational reliability and availability.		5. Automated Monitoring and Diagnostic Systems • Further system integration work appears to be required to adapt head-up display technology for monitoring and diagnostic systems. • Investigate major parameters and components affecting reliability of flight-critical systems (engines, gearbox, rotors, control systems, etc.) and concepts for providing correlated information to the pilot on in-flight failures. • Investigate concepts for an integrated power management system for monitoring (and possibly controlling) aircraft performance limits to improve safety margin for near-limit aircraft operations.
6. Contingency Power • Develop engine technology and/or other contingency power sources that can be activated by the pilot as a short period increase in available power beyond maximum rated power. (Idea is to sacrifice the power source if necessary to save the aircraft. PSH users have stated a similar technology need.)	NASA 505-42-32 Army 6.22.09A/AH76C • Contingency power feasibility tests.				6. Contingency Power • Investigate power management system concepts for integrating feasible contingency power technology into rotorcraft power control systems.

VI. CONCLUSIONS AND RECOMMENDATIONS

CONCLUSIONS

Based upon the results of this review and analysis of aviation mishap investigation reports of helicopter accidents attributed to human error, it is concluded that:

1. The data base on U.S. Army aircraft accidents at the U.S. Army Safety Center, Fort Rucker, Alabama, does provide sufficient documentation of helicopter accidents to identify areas in which new technology could reduce or potentially eliminate human error as a cause factor.

2. There is potential for reducing helicopter accidents by providing improvements in technology which would:

    a. Enhance the pilot's ability to detect and avoid obstacles to safe flight during low altitude and hover flight under restricted visibility conditions.

    b. Reduce tail rotor vulnerability and enhance helicopter capabilities to operate in remote areas.

    c. Enhance the pilot's ability to better determine altitude and rate of descent during autorotation.

    d. Provide essential flight information within the pilot's field of view and eliminate the need to transition to "head-in-cockpit" flight instruments during inadvertent encounters with instrument meteorological conditions (IMC).

    e. Aid the pilot during flight critical situations to avoid confusion and perform necessary pilot functions.

    f. Monitor flight-critical systems and provide early warning of impending system failures and malfunctions.

    g. Provide information on aircraft performance capabilities for existing operating conditions (including power required and power available for out-of-ground-effect hover).

    h. Provide a source of contingency power.

3. Technology areas in which there appears to be a need for new or increased emphasis include:

   a. Vehicle design (eliminate tail rotor).
   b. Advanced flight simulators for pilot training in emergency procedures.
   c. Advanced flight control and display systems.
   d. Obstruction detection devices.
   e. Automated monitoring and diagnostic systems.
   f. Contingency power capabilities.

4. There are some helicopter accidents attributed to human error which involve human actions for which technology applications do not appear to be feasible for reducing or eliminating the underlying cause. (These actions were described in Section IV.)

5. Technology exists within the current state-of-the-art which could contribute to reducing human error as a cause factor in some types of accidents (e.g., Doppler system inputs to autopilot to maintain stable hover under low visibility conditions).

RECOMMENDATIONS

Based upon the results of the review and analysis, the following recommendations are made for NASA consideration:

1. NASA/OAST examine research activities to plan specific tasks for advancing technologies which can, if applied, substantially reduce pilot error as a cause factor in helicopter accidents. Areas for priority emphasis should include:

   a. Technology to provide alternatives to use of a tail rotor for directional control in single rotor configurations.

   b. Advanced technology in flight simulators for applications in pilot proficiency training in emergency procedures.

   c. Obstruction detection devices for use in low altitude operations.

   d. Automated monitoring and diagnostic systems to monitor trends in flight-critical systems and provide the pilot with in-flight information on aircraft performance capabilities (e.g., excess power available, tail rotor effectiveness, etc.).

   e. Contingency power capabilities for application in flight situations where short-term excess power demands could result in loss of the aircraft.

   f. Advanced flight control and display systems to reduce pilot workload in performing flight control functions and support safe operations in both congested and remote areas under obscured vision flight conditions.

2. NASA, in coordination with the U.S. Army, investigate human factors aspect of pilot techniques which may involve attempts to knowingly operate an aircraft outside the design flight profile capabilities of the aircraft.

3. NASA, in coordination with the FAA, military services, and civil helicopter users, establish a task force to investigate the relationships between required pilot workload and human error as a cause factor in helicopter accidents.

APPENDIX

DATA FORMS FOR TECHNICAL REPORT OF HELICOPTER ACCIDENTS

TECHNICAL REPORT OF HELICOPTER ACCIDENT
SUMMARY

1. CLASSIFICATION: ☐ A ☐ B ☐ C ☐ D ☐ E

2. TYPE EVENTS: a. | b. | c.

3. TIME OF DAY: 1 ☐ DAWN 2 ☐ DAY 3 ☐ DUSK 4 ☐ NIGHT

8. a. MISSION, TYPE, DESIGN, SERIES

10a. ESTIMATED COSTS ☐ TOTAL LOSS

ACFT DAMAGE COST	$	OWNER
REPAIR M/HRS	$	
OTHER DAMAGE MIL	$	OWNER
OTHER DAMAGE CIV	$	OWNER
INJURY COST	$	
TOTAL COST THIS ACFT	$	
b. TOTAL COST MULTIPLE ACFT EVENT	$	

9. TOTAL NUMBER OF AIRCRAFT INVOLVED

11. SURVIVABILITY: 1. ☐ SURVIVABLE 2. ☐ PARTIALLY SURV 3. ☐ NON SURVIVABLE 4. ☐ ACFT MISSING

12. INFLIGHT ESCAPE: 1. ☐ EJECTION 2. ☐ BAILOUT 3. ☐ NOT ACCOMPL. 4. ☐ NA

13. FIRE: a. ☐ NONE 1. ☐ INFLIGHT 2. ☐ POST CRASH 3. ☐ OTHER

14. POST CRASH ESCAPE DIFFICULTIES: 1. ☐ YES 2. ☐ NO

15. FUEL	LB FUEL
a. AT TAKE OFF	
b. AT TIME OF EMERG.	
c. TERMINATION	

16. FLAMMABLE FUEL SPILLAGE:
- NONE 0 ☐
- FUEL 1 ☐
- ENGINE OIL 2 ☐
- HYDRAULIC FLUID 3 ☐
- TRANSMISSION OIL 4 ☐
- CARGO 5 ☐
- UNDETERMINED 9 ☐
- OTHER (Specify) 8 ☐

17. CLEARANCE:
- VFR 0 ☐
- IFR 1 ☐
- NONE 2 ☐
- LOCAL 0 ☐
- ITINERANT 1 ☐

18. MISSION

19. INJURIES (Number)	FATAL A	DISABLING B - E	NONDISABLING F - G	MISSING, PRESUMED DEAD H	NOT INJURED J
a. OCCUPANTS MILITARY					
b. OCCUPANTS OTHER					
c. NON-OCCUPANTS MIL					
d. NON-OCCUPANTS OTHER					
e. TOTAL THIS ACFT					
f. MULTIPLE ACFT EVENT					

20. TERRAIN OF CRASH SITE (More than one may apply)

a. GEN CHARACTERISTICS: 14 ☐ MOUNTAIN 08 ☐ FLAT TERRAIN 13 ☐ DESERT 11 ☐ ROLLING 09 ☐ WATER

b. AT MISHAP SITE: 12 ☐ LEVEL 07 ☐ SLOPE

c. SURFACE AT MISHAP SITE: 01 ☐ PREPARED 04 ☐ ICE 02 ☐ SOD 15 ☐ SNOW 03 ☐ SOGGY 16 ☐ WATER

d. OBSTACLES AT MISHAP SITE: 17 ☐ STUMPS 05 ☐ TREES 10 ☐ BLDG 18 ☐ WIRES 06 ☐ ROCKS/BOULDERS 99 ☐ OTHER

21. FLIGHT DATA

	FLIGHT DURATION	PHASE OF OPERATIONS	ALTITUDE AGL	ALTITUDE MSL	AIRSPEED KIAS	HEADING (Compass)	AIRCRAFT WEIGHT	DENSITY ALTITUDE	OVERGROSS YES	OVERGROSS NO
a. PLANNED	HR TNS									
b. WHEN EMERGENCY OCCURRED	HR TNS									
c. ACCIDENT SEQUENCE TERMINATION	HR TNS									

22. ACCIDENT CAUSE FACTORS (Enter a "D" or "S" in appropriate blocks to identify definite or suspected causes)

a. PERSONNEL			PERSONNEL (Continued)		
(1) FLIGHT CREW:	DUTY		(3) SUPERVISORY	DUTY	
	DUTY			DUTY	
	DUTY		(8) OTHER	DUTY	
(2) GROUND CREW:	DUTY		b. MATERIAL FAILURE/MALFUNCTION		
	DUTY		c. ENVIRONMENTAL		

23. SEQUENCE (Enter a concise summary of accident sequence from onset of emergency through termination of flight.)

24. REPORT NUMBER:

MODIFIED FORM 1-R

TECHNICAL REPORT OF HELICOPTER ACCIDENT

FINDINGS OF ACCIDENT BOARD

1. FINDINGS *(Attach additional sheet, if required)*

2. SUMMARY OF ACCIDENT CAUSES, SYSTEM INADEQUACIES AND RECOMMENDATIONS

		SYSTEM INADEQUACIES	REMEDIES		
a. PERSONNEL ERROR		1.	1.	2.	3.
DUTY CODE		2.	1.	2.	3.
TASK ERROR CODE		3.	1.	2.	3.
b. PERSONNEL ERROR		1.	1.	2.	3.
DUTY CODE		2.	1.	2.	3.
TASK ERROR CODE		3	1.	2.	3.
c. PERSONNEL ERROR		1.	1.	2.	3.
DUTY CODE		2.	1.	2.	3.
TASK ERROR CODE		3.	1.	2.	3.
d. MATERIAL FAILURE/MALFUNCTION		1.	1.	2.	3.
FAILURE CODE		2.	1.	2.	3.
		3.	1.	2.	3.
e. ENVIRONMENTAL		1.	1.	2.	3.
ENVIRONMENTAL CODE		2.	1.	2.	3.
		3.	1.	2.	3.

3. REPORT NUMBER:

MODIFIED FORM 2-R

TECHNICAL REPORT OF HELICOPTER ACCIDENT

NARRATIVE

1. NARRATIVE ACCOUNT OF INVESTIGATION
2. REPORT NUMBER:

MODIFIED FORM 3-R

TECHNICAL REPORT OF HELICOPTER ACCIDENT

WRECKAGE DISTRIBUTION DIAGRAM

1. GRID: SHOW MAJOR GOUGE MARKS, DISTRIBUTION OF WRECKAGE, OBSTACLES, DIRECTION OF NORTH, WIND DIRECTION, WIND VELOCITY, POSITION OF WITNESS, ETC. SUGGESTED SCALE: 1" EQUALS 40' ACTUAL SCALE: 1" EQUALS ________

2. REPORT NUMBER:

MODIFIED FORM 5-R

TECHNICAL REPORT OF HELICOPTER ACCIDENT
IN-FLIGHT OR TERRAIN IMPACT AND CRASH DAMAGE DATA

1. INFLIGHT COLLISION KINEMATICS AT INSTANT OF IMPACT

a. AIRSPEED AT IMPACT *(Knots)*

b. VERTICAL SPEED *(Feet per minute)* ______________ .
☐ UP ☐ DOWN

c. WIND VELOCITY AT IMPACT *(Knots)*

d. WIND DIRECTION AT IMPACT *(Degrees)*

e. FLIGHT PATH ANGLE *(Degrees)* ______________ .
☐ UP ☐ DOWN

f. INFLIGHT ATTITUDE AT IMPACT

(1) PITCH ANGLE

(2) ROLL ANGLE

DEGREES ________ ☐ UP ☐ DOWN DEGREES ______ ☐ L ☐ R

g. OBSTACLE IDENTITY AND LOCATION

OBSTACLE	COLLISION HEIGHT ABOVE GROUND *(Feet)*
(1) ☐ BIRDS	
(2) ☐ AIRCRAFT	
(3) ☐ WIRES/CABLES	
(4) ☐ VEHICLES	
(5) ☐ TREE	
(6) ☐ OTHER	

i. OBSTACLE CONSPICUITY *(Within avoidance distance from pilots position, the obstacle in its surroundings was obscured)*

(1) ☐ COMPLETELY (2) ☐ PARTIALLY (3) ☐ NOT OBSCURED

h. OBSTACLE STRIKE SEQUENCE

(1) ☐ PROP/ROTOR (6) ☐ LWR NOSE/GUN TURRET
(2) ☐ ROTOR MAST (7) ☐ LANDING GEAR
(3) ☐ TAIL ROTOR (8) ☐ WING
(4) ☐ TAIL BOOM (9) ☐ EMPENNAGE
(5) ☐ WINDSCREEN/CANOPY (10) ☐ OTHER *(Specify)*

j. WIRE OR CABLE DESCRIPTION

TYPE	DIA IN INCHES	NO. STRUCK
(1) POWER TRANSMISSION		
(2) TELEPHONE OR TV		
(3) BRACING *(Guy/Support)*		
(4) OTHER *(Specify)*		

(5) WIRE PROTECTION SYSTEM INSTALLED ☐ YES ☐ NO

2. TERRAIN COLLISION KINEMATICS AT INSTANT OF MAJOR IMPACT

a. GROUND SPEED AT IMPACT *(Knots)*

b. VERTICAL SPEED *(Feet per minute)* ______________ .
☐ UP ☐ DOWN

c. FLIGHT PATH ANGLE *(Degrees)* ____________ .
☐ UP ☐ DOWN

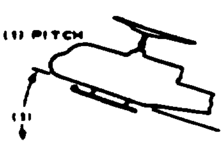
d. INDICATE BY CHECK MARKS WHICH TWO OF THE THREE PRECEEDING PARAMETERS *(a, b, c)* ARE THE MOST ACCURATE.

a. ☐ b. ☐ c. ☐

e. IMPACT ANGLE *(Degrees)*

f. ATTITUDE AT MAJOR IMPACT

(1) PITCH

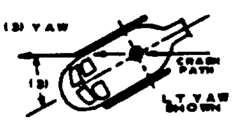


DEGREES ____________ ☐ UP ☐ DOWN

(2) ROLL

DEGREES ________ ☐ LEFT ☐ RIGHT

(3) YAW



DEGREES ____ ☐ LEFT ☐ RIGHT

3. ROTATION AFTER MAJOR IMPACT

a. DID AIRCRAFT ROTATE ABOUT ANY AXIS AFTER THE ABOVE MAJOR IMPACT *(If yes, complete items b, c, and d)*

☐ YES ☐ NO ☐ UNKNOWN

ROTATIONS *(degrees)* / AIRCRAFT AXIS	LEFT	RIGHT
b. ROLL		
c. YAW		

d. FORWARD NOSE OVER *(Degrees)*

4. IMPACT FORCES RELATIVE TO AIRCRAFT AXES *(G's)*

a. VERTICAL *(G's)* ______________ .
☐ UP ☐ DOWN

b. LONGITUDINAL *(G's)* ____________ .
☐ FORE ☐ AFT

c. LATERAL *(G's)* ______________ .
☐ LEFT ☐ RIGHT

5. REPORT NUMBER:

MODIFIED FORM 6-R, Page 1

7. FUSELAGE INWARD DEFORMATION OR COLLAPSE AND INJURY RELATIONSHIP *(Check appropriate boxes)*									
FUSELAGE AREA	AMOUNT OR TYPE OF DEFORMATION OR COLLAPSE	SPECIFIC AREA OF DEFORMATION OR COLLAPSE				(5) FUSELAGE DEFORMATION PRODUCED/CONTRIBUTED TO INJURY			
		Cockpit (1)	Forward Cabin Area (2)	Mid Cabin Area (3)	Rear Cabin Area (4)	Cockpit	Forward Cabin Area	Mid Cabin Area	Rear Cabin Area
a. ROOF	UP TO 1 FOOT								
	MORE THAN 1 FOOT LESS THAN 3 FEET								
	MORE THAN 3 FEET								
b. LEFT SIDE	UP TO 1 FOOT								
	MORE THAN 1 FOOT								
c. RIGHT SIDE	UP TO 1 FOOT								
	MORE THAN 1 FOOT								
d. NOSE	UP TO 1 FOOT								
	MORE THAN 1 FOOT								
e. FLOOR	UP TO 1 FOOT								
	MORE THAN 1 FOOT								
f. FLOOR, *(Local deformation under seats)*	VERTICAL								
	SIDEWARD								
	FORWARD/REARWARD								

8. LARGE COMPONENT DISPLACEMENT *(Check appropriate boxes)*				
COMPONENT	DISPLACED (1)	TORN FREE (2)	PENETRATED/ENTERED	
			COCKPIT (3)	CABIN (4)
a. TRANSMISSION *(Forward or main)*				
b. TRANSMISSION *(Rear)*				
c. ROTOR BLADE *(Forward or main0*				
d. ROTOR BLADE *(Rear)*				
e. LANDING GEAR *(Specify location)*				
f. OTHER *(Specify)*				

9. POSTCRASH FLAMMABLE FLUID SPILLAGE

a. EQUIPPED WITH CRASHWORTHY FUEL SYSTEM ☐ YES ☐ NO

b. IF SO EQUIPPED DID BREAK-AWAY VALVES SEPARATE ☐ YES ☐ NO

c. DID FLAMMABLE FUEL SPILLAGE OCCUR ☐ YES ☐ NO

d. WAS AIRCRAFT EQUIPPED WITH FIRE RESISTANT HYDRAULIC FLUID ☐ YES ☐ NO

e. AMOUNT AND TYPE FLUID SPILLED *(Check box)*

GALLONS	ENGINE FUEL	OIL	HYDRAULIC FUID
0 – 1			
1 – 2			
2 – 10			
10 – 20			
20+			

f. SPILLAGE SOURCE

PART	PART NAME, TITLE, NOMENCLATURE	MANUFACTURERS NO.	NSN
(1) CELL/TANK/RESERVOIR			
(2) FILTER			
(3) FITTING			
(4) FLUID LINE			
(5) VALVE			
(6) BREAKAWAY VALVE			
(7) OTHER *(Specify)*			

10. REMARKS

11. REPORT NUMBER:

MODIFIED FORM 6-R, Page 2

TECHNICAL REPORT OF HELICOPTER ACCIDENT

PERSONAL DATA

1. ROLE OF THIS INDIVIDUAL

a. COMMITTED ERRORS THAT CAUSED/CONTRIBUTED TO ACCIDENT	b. AT CONTROLS WHEN ACCIDENT OCCURRED	c. DUTY STATUS
(1) ☐ DEFINITELY (3) ☐ NO (2) ☐ SUSPECTED (4) ☐ UNKNOWN	(1) ☐ YES (2) ☐ NO	(1) ☐ ON DUTY (2) ☐ OFF DUTY

2. BACKGROUND DATA

a. [redacted]		j. HOURS WORKED LAST 72 HOURS	
b. [redacted]		k. DUTY HOURS REMAINING THIS DAY AFTER ACCIDENT OCCURRED	
c. HOURS SLEPT LAST 24 HOURS		l. HEIGHT *(Inches)*	
d. HOURS SLEPT LAST 48 HOURS		m. WEIGHT *(Pounds)*	
e. HOURS SLEPT LAST 72 HOURS		n. AGE	
f. HOURS AWAKE PRIOR TO ACCIDENT		o. HOURS FLOWN LAST 24 HOURS	
g. HOURS DURATION LAST SLEEP PERIOD		p. HOURS FLOWN LAST 48 HOURS	
h. HOURS WORKED LAST 24 HOURS		q. HOURS FLOWN LAST 72 HOURS	
i. HOURS WORKED LAST 48 HOURS			

3. CREWMEMBER DATA

a. [redacted]		o. MTDS AIRCRAFT FLOWN LAST 60 DAYS ASP/IP	(1)
b. [redacted]			(2)
c. [redacted]			(3)
d. WAIVERS ☐ YES ☐ NO		p. MTDS AIRCRAFT QUALIFIED/CURRENT IN	(1)
			(2)
e. FAC 1 ☐ 2 ☐ 3 ☐ [redacted]			(3)
		q. ATM TASK NUMBER ASSOCIATED WITH INITIAL INDICATION OF EMERGENCY	
f. ARL 1 ☐ 2 ☐ 3 ☐ [redacted]		(1) LAST PERFORMED [redacted] (Months Since)	
g. [redacted]		(2) NUMBER OF ITERATIONS	
h. [redacted]		r. ATM TASK NUMBER INVOLVED IN RESPONSE TO EMERGENCY	
i. [redacted]			
j. [redacted]		(1) LAST PERFORMED [redacted] (Months Since)	
k. MOST RECENT EVALUATION FLIGHT IN MISHAP MTDS AIRCRAFT [redacted] (Months Since)		(2) NUMBER OF ITERATIONS	
		s. POST-ACCIDENT FLIGHT [redacted] (Yes, No)	
		RESULT	
l. NVG QUALIFIED ☐ YES ☐ NO		t. POST-ACCIDENT MEDICAL EXAMINATION/AUTOPSY [redacted] (Yes, No)	
m. IP ☐ SIP ☐ IFE ☐ MTP ☐ VT ☐		REQUIRED LAB TESTS ACCOMPLISHED ☐ YES ☐ NO	
n. PRIMARY AIRCRAFT MTDS		u. LOW PRESSURE/HIGH ALTITUDE CHAMBER ☐ YES ☐ NO	
		v. EJECTION SYSTEM QUAL ☐ YES ☐ NO	

4. FLYING EXPERIENCE

TYPE EXPERIENCE AND TIME	FIXED WING		ROTARY WING		TOTAL	WEATHER	MISHAP AIRCRAFT	
	SINGL ENG	MULTI ENG	SINGL ENG	MULTI ENG		INST	DESIGN	SERIES
a. INSTRUCTOR PILOT								
b. PILOT								
c. COPILOT								
d. CIVILIAN PILOT								
e. TOTAL TIME								
f. COMBAT TIME								
g. FLT SIMUL/SYNTH TRAINER								
h. TOTAL TIME LAST 30 DAYS								
i. TOTAL TIME LAST 60 DAYS								

j. MONTHLY FLIGHT HOURS PAST 12 MONTHS												
(1) [redacted]	—	—	—	—	—	—	—	—	—	—	—	THIS MO.
(2) HOURS												

5. REPORT NUMBER:

MODIFIED FORM 8-R, Page 1

7. MAINTENANCE AND SUPPORT PERSONNEL DATA		
a. PMOS		e. MOS VERIFICATION
(1) DATE AWARDED [redacted] (MONTHS SINCE)	(2) SOURCE ☐OJT ☐AIT ☐CIVIL EXP ☐UNK	(1) SQT ☐GO ☐NO GO (2) DEFINE TASK PERFORMANCE ☐CORRECT ☐INCORRECT ☐NA (3) PERCENT GO ON SCOREABLE UNITS ________ % (4) OVERALL PERCENTILE ________ % (5) SQT WAIVERED ☐YES ☐NO
b. SMOS		
(1) DATE AWARDED [redacted] (MONTHS SINCE)	(2) SOURCE ☐OJT ☐AIT ☐CIVIL EXP ☐UNK	f. CIVILIAN JOB SERIES OR TITLE
c. DMOS		
d. DEFICIENT TASK NO.		(1) TASK RELATED TO JOB DESCRIPTION ☐YES ☐NO
(1) DMOS RELATED ☐YES ☐NO (2) TASK INTERRUPTED OR DELAYED ☐YES ☐NO		(2) PERFORMANCE STANDARDS FOR TASK ☐YES ☐NO

8. LABORATORY TESTS				
TYPE TEST	SPECIMEN TESTED	RESULTS	NAME OF DRUG	[redacted]
a. CARBON MONOXIDE				
b. ALCOHOL				
c. DRUG SCREEN				
d. OTHER				

9. HISTORY OF DESEASES/DEFECTS							
DIAGNOSIS	METHOD OF DISCOVERY				WAIVERS		[redacted]
	ANL PHY	SICK CALL	AUT-OPSY	OTHER	AUTH	[redacted]	

10. REMARKS

11. REPORT NUMBER:

MODIFIED FORM 8-R, Page 2

TECHNICAL REPORT OF HELICOPTER ACCIDENT
INJURY/OCCUPATIONAL ILLNESS DATA

1. DEGREE OF INJURY

a. ☐ FATAL
b. ☐ PERMANENT TOTAL DISABILITY
c. ☐ PERMANENT PARTIAL DISABILITY
d. ☐ LOST WORKDAY CASE *(Days away from work)*
e. ☐ LOST WORKDAYS *(Days of restricted work activity)*
f. ☐ NONFATAL WITHOUT LOST WORKDAYS
g. ☐ FIRST AID ONLY
h. ☐ MISSING & PRESUMED DEAD

2. NUMBER OF LOST WORKDAYS

a. DAYS AWAY FROM WORK	b. DAYS HOSPITALIZED	c. DAYS RESTRICTED ACTIVITY

3. UNCONSCIOUS		4. AMNESIA		
a. HRS	b. MIN	a. ☐ RETROGRADE: HRS MIN	b. ☐ ANTEGRADE: HRS MIN	c. ☐ NONE

5. INJURIES

INJURY SEQ NO. a.	INJURIES: BODY REGION b.	ASPECT c.	BODY RGN QUALIFIER d.	INJURY TYPE RESULT e.	SEVERITY f.	FOR USASC USE (cost) g.	MECHANISM: ACTION h.	QUALIFIER i.	CAUSE FACTORS: SUBJECT j.	ACTION k.	QUALIFIER l.	FOR USASC USE (Weighted cost) m.

6. REMARKS *(Use additional sheet if required)*

7. AUTOPSY PERFORMED a. ☐ YES b. ☐ NO c. ☐ PROTOCOL ATTACHED d. ☐ WILL BE FORWARDED

8. CAUSE OF DEATH	9. DUTY STATUS a. ☐ ON DUTY b. ☐ OFF DUTY

9. REPORT NUMBER:

MODIFIED FORM 9-R

TECHNICAL REPORT OF HELICOPTER ACCIDENT

PERSONNEL PROTECTIVE/ESCAPE/SURVIVAL/RESCUE DATA

1. DID THIS INDIVIDUAL SUSTAIN AN INJURY OR OCCUPATIONAL ILLNESS BECAUSE OF ACCIDENT ☐ YES ☐ NO

2. PERSONNEL PROTECTIVE/RESTRAINT/SURVIVAL EQUIPMENT

ITEM	TYPE (1)	RE-QUIRED (2)	NEEDED (3)	AVAIL-ABLE (4)	USED (5)	PRODUC-ED AL-LOWED INJURY (6)	PRE-VENTED INJURY (7)	RE-DUCED INJURY (8)	FUNC-TIONED AS DE-SIGNED (9)	INFORMATION CODES (10)			
a. HELMUT													
b. VISOR													
c. GLASSES													
d. FLIGHT SUIT													
e. FLIGHT GLOVES													
f. FLIGHT JACKET													
g. BOOTS													
h. OTHER CLOTHING													
i. LAP BELT													
j. SHOULDER HARNESS													
k. GUNNER HARNESS													
l. INERTIA REEL													
m. SEAT/LITTER													
n. SURVIVAL EQUIP													
o.													
p.													

3. PERSONNEL EVACUATION/ESCAPE	INFORMATION CODES				
a. METHOD OF ESCAPE					
b. LOCATION IN AIRCRAFT					
c. EXIT ATTEMPTED					
d. EXIT USED					
e. AIRCRAFT ATTITUDE DURING ESCAPE					
f. COCKPIT/CABIN CONDITIONS					
g. ESCAPE DIFFICULTIES					

4. LAPSED TIME FOR RESCUE

	DATE		HOUR OF DAY		LAPSED TIME		5. DISTANCE FROM ACCIDENT TO ACTUAL RESCUE VEHICLE AT TIME OF ACCIDENT
	MM	DD	HR	MIN	HR	MIN	
a. NOTIFICATION OF RESCUE PERSONNEL							a. TO AIRCRAFT IN NAUTICAL MILES
b. INDIV PHYSICALLY REACHED							
c. INDIV ACTUALLY ABOARD RESCUE VEH							b. TO GROUND VEHICLE IN STATUTE MILES
d. RESCUE COMPLETED/ABANDONED							

6. PERSONNEL SURVIVAL/RESCUE	INFORMATION CODES								
a. SURVIVAL PROBLEMS ENCOUNTERED									
b. MEANS USED TO LOCATE INDIVIDUAL									
c. RESCUE EQUIPMENT USED									
d. FACTORS THAT HELPED RESCUE									
e. FACTORS COMPLICATING RESCUE									
f. INDIVIDUAL PHYSICAL CONDITION									

g. VEHICLES ACTUALLY PERFORMING EVAC *(Specify)*

h. OTHER VEHICLE ASSISTING IN RESCUE *(Specify)*

7. REMARKS *(Use additional sheet, if required)*

8. REPORT NUMBER:

MODIFIED FORM 10-R

TECHNICAL REPORT OF HELICOPTER ACCIDENT

WEATHER DATA

1. ROLE OF WEATHER							
a. DEFINITE D		b. SUSPECTED S		c. NONE W		d. UNDETERMINED Z	

2. GENERAL DATA AT TIME OF OCCURRENCE					
a. TEMPERATURE *(degrees Cent.)*		b. ALTIMETER SETTING *(HG)*		c. ALTIMETER READING *(Feet)*	

3. SKY CONDITION	ACCIDENT SEQUENCE: INITIAL INDIC OF EMERG	AT EMERGENCY	DURING DESCENT	ACCIDENT OR TERMATION
a. ○ CLEAR				
b. ⦶ SCATTERED (feet)				
c. ⦷ BROKEN (feet)				
d. ⊕ OVERCAST (feet)				
e. −X PARTIAL OBSCURATION				
f. X OBSCURATION				
x. UNKNOWN				
4. HORIZON				
a. VISIBLE				
b. PARTIALLY OBSCURED				
c. OBSCURED				
5. VISIBILITY *(Naut. miles)*				
6. OBSTRUCTION TO VISION				
a. NATURAL				
01. DUST				
02. FOG				
03. GROUND FOG				
04. HAZE				
05. ICE FOG				
06. SMOKE				
07. BLOWING DUST				
08. BLOWING SAND				
09. BLOWING SNOW				
00. NONE				
98. OTHER *(Specify)*				
b. INDUCED *(Rotorwash, etc.)*				
01. BLOWING SNOW				
02. BLOWING SAND				
03. BLOWING DUST				
04. BLOWING SPRAY				
00. NONE				
98. OTHER *(Specify)*				

7. WINDS	
a. ALOFT *(At enroute altitude)*	
(1) DIRECTION *(Degrees Mag.)*	(2) VELOCITY *(Kt)*
b. SURFACE WINDS	
(1) LANDING DIR. *(Degrees Mag.)*	(2) SURFACE WIND DIR. AND VARIANCE *(Degrees Mag.)*
(3) SURFACE WIND VELOCITY AND GUST SPREAD *(Kt)*	

8. AIRCRAFT ICING — NONE 0 ☐ YES 1 ☐

8. AIRCRAFT ICING	ICING SEVERITY: TRACE (1)	LIGHT (2)	MODERATE (3)	SEVERE (4)
01. MAIN MOTOR BLADES				
02. WINGS				
03. PROPELLERS				
04. CONTROL SURFACES				
05. ROTOR HEAD				
06. TAIL ROTOR				
07. FUSELAGE				
08. PITOT STATIC SYSTEM				
09. CARBURETOR				
10. ENGINE AIR INLET				
11. FUEL VENTS				
12. ANTENNA				
13. WINDSCREEN				
98. OTHER *(Specify)*				

9. SIGNIFICANT WEATHER *(A maximum of three may be selected)*	ACCIDENT SEQUENCE: INITIAL INDIC OF EMERG	AT EMERGENCY	DURING DESCENT	ACCIDENT OR TERMINATION
01. HAIL				
03. SLEET				
05. ICE CRYSTALS				
06. DRIZZLE				
07. RAIN				
09. SNOW				
12. LIGHTNING				
13. THUNDER STORM				
14. FREEZING DRIZZLE				
15. FREEZING RAIN				
16. GUSTY WINDS				
97. UNKNOWN				
00. NONE				
98. OTHER *(Specify)*				

10. TURBULENCE

NONE 0 ☐ YES 1 ☐ *(If "YES" enter below "C" for continuous, "I" for intermittent, and "O" for occasional)*

10. TURBULENCE				
a. LIGHT				
b. MODERATE				
c. SEVERE				
d. EXTREME				

11. FORECAST

CORRECT C ☐ INCORRECT I ☐ UNKNOWN U ☐

12. REMARKS *(Use additional sheet if required)*

13. REPORT NUMBER:

MODIFIED FORM 11-R

TECHNICAL REPORT OF HELICOPTER ACCIDENT

FIRE DATA

1. FIRE STARTED *(Check D — Definite S — Suspected)*	D	S
a. INFLIGHT		
b. UPON IMPACT *(Less than 1 minute)*		
c. UPON IMPACT *(More than 1 minute)*		
d. DURING REFUELING		
y. OTHER *(Specify)*		
z. UNDETERMINED ☐		

2. INDICATIONS OF FIRE *(More than 1 May apply, enter 1, 2 or 3 to show sequence)*

a. ☐ FIRE WARNING SYSTEM d. ☐ SMELL
b. ☐ OTHER INSTRUMENTS e. ☐ EXPLOSION *(Sound)*
c. ☐ SIGHT f. ☐ EXTERNAL COMMO
y. ☐ OTHER *(Specify)*

3. INITIAL AND PRINCIPAL LOCATION OF FIRE *(Enter 1 to indicate initial location, 2 to indicate principal location)*	D	S
01. ENGINE SECTION		
02. TRANSMISSION SECTION		
03. COCKPIT		
04. TAIL ASSEMBLY		
05. PASSENGER SECTION		
06. OXYGEN SYSTEM		
07. BAGGAGE COMPARTMENT		
08. EXTERNAL STORES		
09. FLARE POD		
10. ROCKET POD		
11. AMMUNITION STORES		
12. AVIONIC SECTION		
13. APU		
14. WHEEL WELL		
15. WHEEL BRAKE		
16. TAILPIPE		
17. INSTRUMENT PANEL		
18. BATTERY COMPARTMENT		
19. JUNCTION BOX		
20. HEATER COMPARTMENT		
21. FUEL CELL		
22. WING		
23. GUN TURRET		
24. TAIL BOOM		
25. CARGO SECTION		
26. TIRES		
98. OTHER *(Specify)*		
99. UNDETERMINED ☐		

4. IGNITION SOURCE	D	S
a. EXHAUST FLAMES		
b. SPARKS, FRICTION, e.g., SKIDDING		
c. ELECTRICAL SPARKS		
d. HOT SURFACES, e.g., EXHAUST DUCTS		
e. AIRCRAFT SUBSYSTEM		
f. AIRCRAFT OCCUPANT, e.g., LIGHTED CIGAR		
g. EXTERNAL OF AIRCRAFT, e.g., GRASS FIRE		
h. CARGO		
i. EXPLOSIVES		

4. IGNITION SOURCE *(Continued)*	D	S
j. SHORT CIRCUIT		
k. LIGHTNING		
l. STATIC ELECTRICITY		
m. OTHER *(Specify)*		
n. UNDETERMINED ☐		

5. COMBUSTIBLE MATERIAL	D	S
a. MAIN FUEL		
b. AUXILIARY FUEL		
c. HYDRAULIC FLUID		
d. ENGINE OIL		
e. TRANSMISSION OIL		
f. ELECTRICAL INSULATION		
g. ACOUSTICAL MATERIALS		
h. METAL *(Specify)*		
i. EXPLOSIVES		
j. UPHOLSTERY MATERIALS		
k. CARGO		
m. EXTERNAL MATERIAL *(Specify)*		
y. OTHER *(Specify)*		
z. UNDETERMINED ☐		

6. FIRE EXTINGUISHING SYSTEM	GND a.	b. AIRCRAFT INST.	PORT.
(1) NO EFFECT WHEN DISCHARGED			
(2) ACTIVATED, BUT DID NOT DISCHARGE			
(3) REDUCED FIRE			
(4) EXTINGUISHED FIRE			
(5) NOT ACTIVATED AND NOT NEAR FIRE			
(6) NOT ACTIVATED, BUT NEAR FIRE			
(7) NOT INSTALLED			

7. FIRE/SMOKE DETECTION SYSTEM	YES 1	NO 2	UN-DETM. 9
a. SYSTEM INSTALLED			
b. WARNING SYSTEM OPERATED PROPERLY			
c. SENSORS WITHIN RANGE OF			

8. EFFECT OF EMER SHUTOFF PROCEDURE *(Enter D, S, or Unk)*	ENG	FUEL	ELECT
a. EXTINGUISHED FLAME			
b. REDUCED FIRE			
c. NO EFFECTS			
d. NOT ACCOMPLISHED			
e. USED FAULTY PROCEDURE			

9. GENERAL DATA

a. EST OF AIRCRAFT FIRE DAMAGE *(Excl of impact damage)*
(1) ☐ 0-25% (2) ☐ 26-50% (3) ☐ 51-75% (4) ☐ 76-100%

b. FIRE DIMENSION: TO CLEAR FIRE, AIRCRAFT OCCUPANTS HAD TO MOVE *(Feet)*:

c. TOXICITY: WAS THERE EVIDENCE OF TOXIC PRODUCTS.
☐ 1 YES ☐ 0 NO *(If yes, name, co, etc.)*:

d. DISTANCE TO NEAREST AVAIL MIL FIREFLIGHTING EQUIPMENT (1) AIRMILES *(NM)*: (2) ROAD MILES *(SM)*:

e. IS AIRCRAFT EQUIPPED WITH CRASH RESISTANT ☐ 1 YES
(1) FUEL CELLS ☐ 1 YES ☐ 0 NO (2) FUEL LINES ☐ 0 NO

10. REMARKS *(Use separate sheet of paper)*

11. REPORT NUMBER:

MODIFIED FORM I2-R

TECHNICAL REPORT OF HELICOPTER ACCIDENT TECHNOLOGY FACTORS
1. ASSESSMENT OF TECHNOLOGY IMPLICATIONS (Use additional sheet, if required)
2. TYPES OF NEW TECHNOLOGY NEEDS
3. RATIONALE FOR NEW TECHNOLOGY
4. REPORT NUMBER:

1. Report No. NASA CR-3895 ORI TR-2384	2. Government Accession No.	3. Recipient's Catalog No.
4. Title and Subtitle Investigation of Technology Needs for Avoiding Helicopter Pilot Error Related Accidents - Final Report		5. Report Date May 1985
		6. Performing Organization Code
7. Author(s) Richard I. Chais and William E. Simpson		8. Performing Organization Report No. TR-2384
9. Performing Organization Name and Address ORI, Inc. 1375 Piccard Drive Rockville, MD 20850		10. Work Unit No.
		11. Contract or Grant No. NASW-3554, Task 016
12. Sponsoring Agency Name and Address Office of Aeronautics and Space Technology National Aeronautics and Space Administration Washington, D.C. 20546		13. Type of Report and Period Covered Contractor Report
		14. Sponsoring Agency Code RJ

15. Supplementary Notes

Project Monitor, John F. Ward

16. Abstract

Pilot error is cited as a cause or related factor in most rotorcraft accidents.

This report documents the study effort to investigate pilot error related accidents in helicopters to identify areas in which new technology could reduce or eliminate the underlying causes of these human errors. The study drew from the aircraft accident data base at the U.S. Army Safety Center at Ft. Rucker, Alabama, as the source of data on helicopter accidents. The analytical approach involved review of a randomly selected sample of 110 accident records on a case-by-case basis to assess the nature of problems which need to be resolved and applicable technology implications. The report identifies six technology areas in which there appears to be a need for new or increased emphasis.

17. Key Words (Suggested by Author(s)) Rotorcraft Technology Needs Helicopter Safety Pilot Error Accidents Rotorcraft Accident Prevention	18. Distribution Statement Unclassified - Unlimited Subject Category 03

19. Security Classif. (of this report) Unclassified	20. Security Classif. (of this page) Unclassified	21. No. of Pages 62	22. Price A04

For sale by the National Technical Information Service, Springfield, Virginia 22161 NASA-Langley, 1985