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INCIDENCE AND COST OF ORIENTATION-ERROR ACCIDENTS IN REGULAR ARMY AIRCRAFT OVER A FIVE-YEAR STUDY PERIOD: SUMMARY REPORT

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This report is a summary account of the results of a joint Army/Navy study of orientation-error aircraft accidents that occurred in Regular Army aviation over a five-year period. Statistical data are presented that indicate spatial disorientation in helicopters is a significant flight hazard very comparable in magnitude to the threat generally accepted as being present with military operation of fixed wing aircraft. Of the total number of accidents that occurred in rotary wing (RW) aircraft over the study period, orientation error accounted for approximately 7.4 percent of the total, 16.5 percent of the total

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number of fatal accidents, 15.8 percent of the total number of fatalities, 9.4 percent of the total number of nonfatal injuries, and 10.3 percent of the total aircraft dollar damage costs. The risk associated with an orientation-error accident that occurred in a RW aircraft was also most significant in that 35 percent of these accidents were fatal. The study also provides quantitative data to validate the high accident risk (not combat losses) of combat-oriented flight operations. For aircraft of all types, the mean accident rate (accidents per 100,000 flight hours) in Vietnam was approximately 2.4 times greater than the rate elsewhere for accidents of all types, 2.1 times greater for pilot-error accidents, and 3.3 times greater for orientation-error accidents.

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Naval Medical Research and Development Command
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U. S. Army Aeromedical Research Laboratory

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SUMMARY PAGE

THE PROBLEM

Although spatial disorientation continues to be a recognized flight hazard in military aviation, the majority of the statistical data available to describe the incidence and cost of the attendant accidents pertain primarily to fixed wing aircraft operations. Few quantitative data are available to describe the magnitude of the accident threat in rotary wing aircraft operations.

FINDINGS

Since helicopters represent the predominant elements of the Army aircraft inventory, a joint Army/Navy research project was implemented to study the incidence of orientation-error accidents that occurred in Regular Army aviation over a five-year period. Previous reports have detailed the magnitude of the problem on an individual fiscal-year basis. This report is a summary account of the salient incidence and cost statistics observed over the entire study period. The data establish that spatial disorientation in rotary wing (RW) aircraft is a significant flight hazard very comparable to the threat generally accepted as being present with military operation of fixed wing aircraft. Of the total number of accidents that occurred in RW aircraft over the study period, orientation error accounted for approximately 7.4 percent of the total, 16.5 percent of the total number of fatal accidents, 15.8 percent of the total number of fatalities, 9.4 percent of the total number of nonfatal injuries, and 10.3 percent of the total aircraft dollar damage costs. The risk associated with an orientation-error accident that occurred in a RW aircraft was also most significant in that 35 percent of these accidents were fatal. The study also provides quantitative data to validate the high accident risk (not combat losses) of combat-oriented flight operations. For aircraft of all types, the mean accident rate (accidents per 100,000 flight hours) in Vietnam was approximately 2.4 times greater than the rate elsewhere for accidents of all types, 2.1 times greater for pilot-error accidents, and 3.3 times greater for orientation-error accidents.

ACKNOWLEDGMENTS

The authors wish to thank Colonel R. W. Bailey, MSC, USA (Ret.), former Commanding Officer of the U. S. Army Aeromedical Research Laboratory, for his continued support and guidance during the conduct of the study.

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INTRODUCTION

Although pilot spatial disorientation in military helicopters is a recognized flight hazard (refs. 1-11), few quantitative data have been available to describe the actual magnitude of the related accident threat.

As a result of the mutual Army/Navy concern for this problem, the U. S. Army Aeromedical Research Laboratory (USAARL), the U. S. Army Agency for Aviation Safety (USAAAVS), and the Naval Aerospace Medical Research Laboratory (NAMRL) organized and implemented a five-year longitudinal study of the incidence and cost of orientation-error accidents that occurred in Army aviation over the fiscal year 1967 through 1971 period. The findings of this study have been detailed on an individual-year basis in three series of reports: One series (refs. 12-16) dealt with the incidence and cost of orientation-error accidents in all types of Army aircraft, both fixed wing (FW) and rotary wing (RW); a second series (refs. 17-21) dealt with similar statistics for only the UH-1 helicopter; and a third series (refs. 22-26) provided a case history description of the operational aspects of all major orientation-error accidents that occurred in the UH-1 over the same period. The present paper is a summary account of the salient incidence and cost statistics derived from the first two series of reports.

To emphasize the over-all magnitude of the orientation-error accident problem, the report gives particular attention to summarizing the mean incidence and mean cost of these accidents on both a relative (percentage) basis, using pilot-error accidents and accidents of all types as measurement references, and on an absolute (numerical) basis. Although the Army aircraft inventory during the study period was composed primarily of rotary wing aircraft, accident statistics dealing with the fixed wing element of the inventory are presented for comparative purposes whenever possible. In an attempt to give some quantitative insight into the generally recognized high accident hazard of combat-oriented flight operations, comparative statistical data are also presented for accidents that occurred in Vietnam and accidents that occurred elsewhere, primarily in the United States.

PROCEDURE

The procedure used to conduct the longitudinal study has been outlined in detail in earlier reports (refs. 12,17,22). As a matter of background, the initial project task was to develop a workable definition of the class of accidents to be identified as involving orientation error (ref. 27) of the pilot. In the development of this definition the term <u>orientation</u> was considered to involve the correct perception of the static and dynamic position and attitude of an aircraft in three-dimensional space. Emphasis was placed on the word dynamic since full knowledge of the motion, as well as static attitude and position, of an aircraft is required to define its true instantaneous spatial orientation. With this definition of the term orientation a pilot is considered to have made an <u>orientation error</u> whenever his perception of the motion, attitude, or altitude of his aircraft differs from the true motion, attitude, or altitude; i.e., the true orientation of the aircraft. An orientation-error accident was then defined as one that occurs as a result of an incorrect power or control action (or the lack of a correct action) taken by a conscious pilot due to his incorrect perception of the true spatial orientation of the aircraft. This definition was qualified in several respects: The accident situation had to be one in which the demands on pilot skill were reasonable; an accident involving only navigation mistakes or difficulties was not classified as involving orientation error (OE); an accident resulting from a collision with low visibility objects, e.g., wire strikes, located in the flight path was not included unless the collision derived from an orientation error (e.g., if an aircraft struck a wire during a controlled descent, the accident was not given an OE classification; if an undetected drift of a hovering aircraft resulted in a collision, then an OE classification resulted); and lastly, it was implicit that the OE classification would not include deliberate or suicidal accident actions.

With these definitions it is implicit that if an orientation error occurs in flight, the pilot is spatially disoriented since his perception of the aircraft orientation differs from the actual or true orientation. The converse is not necessarily true. That is, spatial disorientation can occur without necessarily effecting an orientation error. For example, a pilot could experience a turning sensation following a tactical maneuver and, through the use of his instruments and a view of the outside world, intellectually arrive at a perceived orientation of the aircraft that could be in exact correspondence with the true orientation of the aircraft. Similarly, it is possible that a pilot suffering the leans could intellectually arrive at a true perception of aircraft orientation even though he might orient his body within the aircraft in a nonveridical position. In these cases spatial disorientation exists without orientation error, and the accident hazard is minimized.

When spatial disorientation does occur, the symptoms as manifested by the pilot may be either overt or covert. In the case of overt spatial disorientation the pilot by definition recognizes that he has an orientation problem and that he must make an appropriate move, either to prevent orientation error or to correct an existing orientation-error problem. If the disorienting effects are not incapacitating, and if the time/terrain clearance profile of the aircraft is adequate, then corrective action can prevent an accident. The hazard of a covert spatial disorientation experience, i.e., where the pilot does not recognize that his perceived orientation of the aircraft is in error, is even greater in that he may never recognize the need for corrective action before impact occurs.

In effect, it was the project concept that these definitions would allow a more systematic approach to the always difficult task (ref. 28) of identifying and classifying spatial disorientation accidents. It was also felt that these definitions might provide better insight into the operational aspects of covert as well as overt spatial disorientation experiences that resulted in aircraft accidents.

Using these definitions and interpretations as reference, an experienced accident classifier reviewed all pilot-error (PE) accidents that occurred during the study period and made a preliminary identification of all accidents that might possibly fit into the orientation-error category. The project investigators then reviewed the identified cases and, using the detailed master files associated with each accident as reference, made the final determination as to the orientation-error classification.

RESULTS AND DISCUSSION: ALL AIRCRAFT

The data presented in this section of the report pertain to all accidents that were classified as involving orientation error in Army aircraft of all types over the entire five-year study period (refs. 12-16). Table I contains a summary listing by fiscal year of the basic incidence and cost statistics of the orientation-error accidents with separate and combined tabulations for fixed wing (FW) and rotary wing (RW) aircraft. Selected data from Table I are plotted in Figure 1 to graphically display the year-to-year variations in these data. To facilitate the discussion of these absolute or numeric data in terms of the over-all magnitude of the orientation-error accident problem, reference will be made throughout the paper to equivalent incidence and cost statistics that pertain to 1) pilot-error accidents, i.e., accidents classified by USAAAVS as due primarily to some form of pilot-error causal factor (refs. 29-31), and 2) aircraft accidents of all types which, by definition, include all PE accidents. It also follows that the PE accident classification will include all OE accidents. For reference purposes, incidence and cost data related to the all-accident and PE classifications are separately listed in Tables A1 and A2, respectively, of the Appendix, using a format similar to that of the Table I orientation-error accident data. Since this report is of a summary nature, attention will be given to providing a cursory description in subsection form of what are considered to be the salient findings of the study.

NUMERICAL INCIDENCE AND COST OF ORIENTATION-ERROR ACCIDENTS

As indicated in Table I and Figure 1, a total of 334 major and minor aircraft accidents were classified as involving orientation error of the pilot over the five-year study period. These accidents, 117 of which were fatal, resulted in 332 fatalities, 430 injuries, and a total aircraft damage cost of approximately $65,000,000. Of these total figures, RW aircraft accounted for approximately 92 percent of the total number of OE accidents, 94 percent of the OE fatalities, 97 percent of the OE injuries, and 91 percent of the aircraft dollar costs due to OE.

Examination of the mean data of Table I indicates that, on the average, OE resulted in an annual mean incidence of approximately 67 aircraft accidents, 23 fatal accidents, 66 fatal injuries, 86 nonfatal injuries, and an annual aircraft damage cost of approximately $13,000,000. It should be noted that all of the dollar costs referenced in this report pertain to aircraft damage proper and do not reflect in any manner the extensive costs involved in the loss, injury, or replacement of crew personnel involved in the OE accidents. As may be deduced from the injury and death cost data presented by Zilioli (ref. 32) and by Zilioli and Bisgard (ref. 33) for Army aviators, the personnel costs of such accidents can considerably exceed the direct aircraft damage costs. (See ref. 39 for a current DOD estimate of the dollar cost of personnel losses.)

TABLE I·

YEARLY INCIDENCE AND COST OF ORIENTATION-ERROR ACCIDENTS THAT OCCURRED IN ARMY AIRCRAFT OVER THE 5-YEAR STUDY PERIOD

ALL AIRCRAFT	1967	1968	1969	1970	1971	TOTAL	MEAN
Number of Major Accidents	50	75	68	81	50	324	64·8
Number of Minor Accidents	7	0	3	0	0	10	2·0
Total Number of Accidents	57	75	71	81	50	334	66·8
Accidents per 100,000 Hours	1·55	1·46	1·16	1·29	1·01	-----	1·28
Accidents per 100,000 Landings	0·50	0·48	0·38	0·43	0·35	-----	0·42
Number of Fatal Accidents	19	26	22	25	25	117	23·4
Number of Fatal Injuries	45	91	51	80	65	332	66·4
Number of Nonfatal Injuries	105	75	79	104	67	430	86·0
Total Aircraft Damage-Dollars	10,144,034	12,381,805	11,928,660	19,355,689	11,404,119	65,214,307	13,042,861
ROTARY WING AIRCRAFT	**1967**	**1968**	**1969**	**1970**	**1971**	**TOTAL**	**MEAN**
Number of Major Accidents	49	66	63	75	47	300	60·0
Number of Minor Accidents	6	0	2	0	0	8	1·6
Total Number of Accidents	55	66	65	75	47	308	61·6
Accidents per 100,000 Hours	1·96	1·60	1·29	1·42	1·14	-----	1·44
Accidents per 100,000 Landings	0·54	0·47	0·38	0·43	0·36	-----	0·43
Number of Fatal Accidents	18	21	20	24	23	106	21·2
Number of Fatal Injuries	44	80	46	79	62	311	62·2
Number of Nonfatal Injuries	104	70	78	98	67	417	83·4
Total Aircraft Damage-Dollars	10,116,847	9,077,065	11,724,852	17,060,490	11,191,377	59,170,631	11,834,126
FIXED WING AIRCRAFT	**1967**	**1968**	**1969**	**1970**	**1971**	**TOTAL**	**MEAN**
Number of Major Accidents	1	9	5	6	3	24	4·8
Number of Minor Accidents	1	0	1	0	0	2	0·4
Total Number of Accidents	2	9	6	6	3	26	5·2
Accidents per 100,000 Hours	0·25	0·89	0·56	0·60	0·37	-----	0·55
Accidents per 100,000 Landings	0·17	0·58	0·41	0·41	0·25	-----	0·38
Number of Fatal Accidents	1	5	2	1	2	11	2·2
Number of Fatal Injuries	1	11	5	1	3	21	4·2
Number of Nonfatal Injuries	1	5	1	6	0	13	2·6
Total Aircraft Damage-Dollars	27,187	3,304,740	203,808	2,295,199	212,742	6,043,676	1,208,735

INCIDENCE AND COST OF ORIENTATION-ERROR ACCIDENTS IN ARMY AVIATION OVER FY67-71 PERIOD

--- COMBINED FIXED WING AND ROTARY WING DATA ---

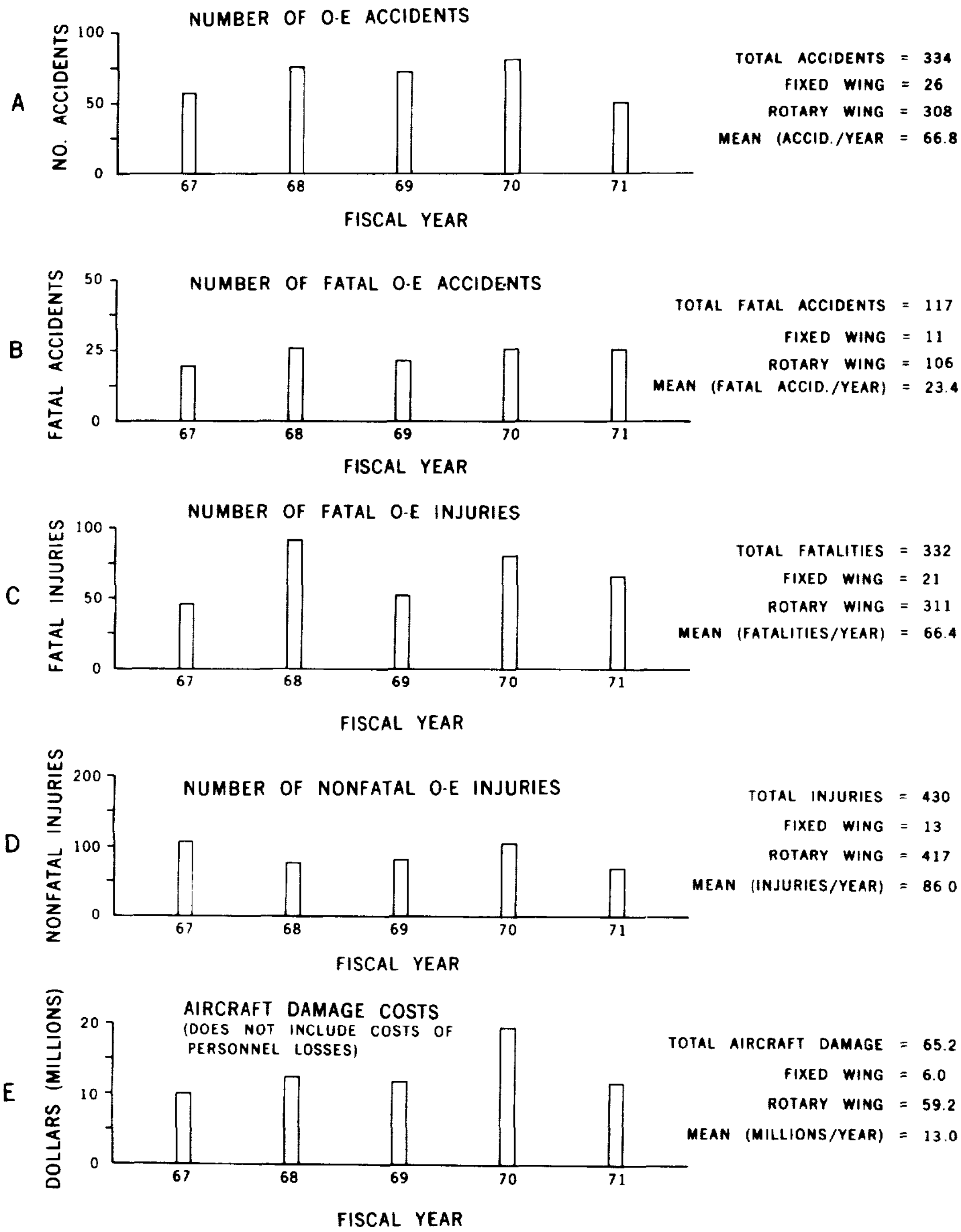


Figure 1.

PERCENTAGE INCIDENCE AND COST OF ORIENTATION-ERROR ACCIDENTS

All-Accidents Measurement Reference

In terms of all accidents, regardless of cause, that occurred in Army aviation over the five-year study period (see Table A1), orientation-error accidents accounted for approximately 7.0 percent of the total number of accidents, 16.1 percent of the total number of fatal accidents, 15.4 percent of the total number of fatalities, 9.1 percent of the total number of nonfatal injuries, and 10.3 percent of the total aircraft damage costs. The year-to-year variations that occurred in each of these percentage figures, based on the combined FW and RW accident data, are plotted in solid outline in Figure 2.

By referring to only the RW accident data of Tables I and A1, it may be seen that the total number of orientation-error accidents that occurred in RW aircraft over the five-year study period accounted for approximately 7.4 percent of the total number of RW accidents, 16.5 percent of the total number of fatal accidents, 15.8 percent of the total number of fatalities, 9.4 percent of the total nonfatal injuries, and 10.3 percent of the total aircraft damage costs. Correspondingly, for the FW accident data of the same two tables it may be shown that the total number of orientation-error accidents that occurred in FW aircraft over the study period accounted for approximately 4.3 percent of the total number of FW accidents, 12.9 percent of the total number of fatal accidents, 11.2 percent of the total number of fatalities, 4.5 percent of the total number of nonfatal injuries, and 10.1 percent of the total aircraft damage costs. These data indicate that, relative to accidents of all types, the contribution of orientation error to the over-all total figures was moderately greater in RW aircraft.

Because of differences in accident classification procedures as well as differences in aircraft types, models, performance capabilities, and missions, it has always been a difficult task to quantitatively weight spatial disorientation accident statistics derived from different incidence studies. In the nonclassified literature, Nuttall and Sanford (ref. 34) reported that in the US Air Force Europe Command during the 1954-1956 period, approximately 4 percent of all major accidents involved pilot "vertigo." These vertigo accidents, involving FW aircraft accounted for approximately 14 percent of the total number of fatal accidents. Neely, Zeller, and Normand (ref. 35) reported that over a two and one-half year period beginning with 1955, vertigo accounted for approximately 2 percent of the total number of major accidents and 5 percent of the total number of fatalities. These data also pertained primarily to FW aircraft. Moser (ref. 36) reported that in the USAF Aerospace Defense Command during the 1964-1967 period, spatial disorientation was considered to be a significant factor in approximately 9 percent of the total number of major accidents. This factor also accounted for approximately 26 percent of the total number of fatal accidents. The data of this study pertained primarily to jet FW aircraft, with 67 percent being high-performance type interceptors. Barnum and Bonner (ref. 37) reported that during the 1958-1968 decade, approximately 6 percent of the major USAF accidents involved spatial disorientation, with 75 percent of these accidents being fatal. Spatial disorientation accounted for approximately 14.4 percent of all fatal accidents and 9.4 percent of all fatalities. In their study helicopter accidents due to spatial disorientation represented only 1 percent of the total number of spatial disorientation accidents. As reported by Gillingham and Krutz (ref. 38), Barnum in a follow-up study covering the 1969-1971 period again found that spatial disorientation accounted for approximately 6 percent of the total number of major accidents. Gillingham also reported that Kellogg in an independent study of USAF accidents during the 1968-1972 period found an annual incidence of spatial disorientation accidents ranging from 4.8 to 6.2 percent.

For the present study, using major accidents as reference, orientation error accounted for approximately 7.2 percent of all major accidents that occurred in aircraft of all types, 7.6 percent of all major RW accidents, and 4.3 percent of all major FW accidents. Because of the small number of minor accidents, these figures differ only slightly from the previously mentioned percentages that were based on the combined total of major and minor accidents. In effect, the data of this study indicate a percentage incidence of orientation-error accidents for RW aircraft that are comparable to the referenced FW incidence data. Again, it is emphasized that this comparison is limited by the previously mentioned differences in accident classification procedures and aircraft/mission parameters as well as by the fact that the data of this study included orientation-error accidents that occurred in the Vietnam combat environment.

Pilot-Error Accidents Measurement Reference

In terms of all pilot-error accidents that occurred in Army aviation over the five-year study period (see Table A2), orientation-error accidents accounted for approximately 10.4 percent of the total number of PE accidents, 24.7 percent of the fatal PE accidents, 24.2 percent of the PE fatalities, 13.4 percent of the PE nonfatal injuries, and 16.5 percent of the total PE aircraft damage costs. The individual-year datum from which these mean data were calculated is shown plotted in dashed outline in Figure 2.

With the RW data of Tables I and A2 as reference it can be shown that the total number of orientation-error accidents that occurred in RW aircraft over the study period accounted for approximately 11.1 percent of the total number of PE accidents that occurred in RW aircraft, 25.5 percent of the total fatal PE accidents, 25.0 percent of the total PE fatalities, 14.0 percent of the total nonfatal PE injuries, and 16.6 percent of the total aircraft damage costs due to PE. The corresponding FW data indicate that FW orientation-error accidents accounted for approximately 5.7 percent of the total number of PE accidents that occurred in FW aircraft, 19.0 percent of the total fatal PE accidents, 16.4 percent of the total PE fatalities, 5.7 percent of the total nonfatal PE injuries, and 15.5 percent of the total FW aircraft damage costs due to PE. Again, as with the all-accident data, these data indicate that the contribution of orientation-error to the over-all pilot-error accident problem was greater for the RW elements of the Army aircraft inventory.

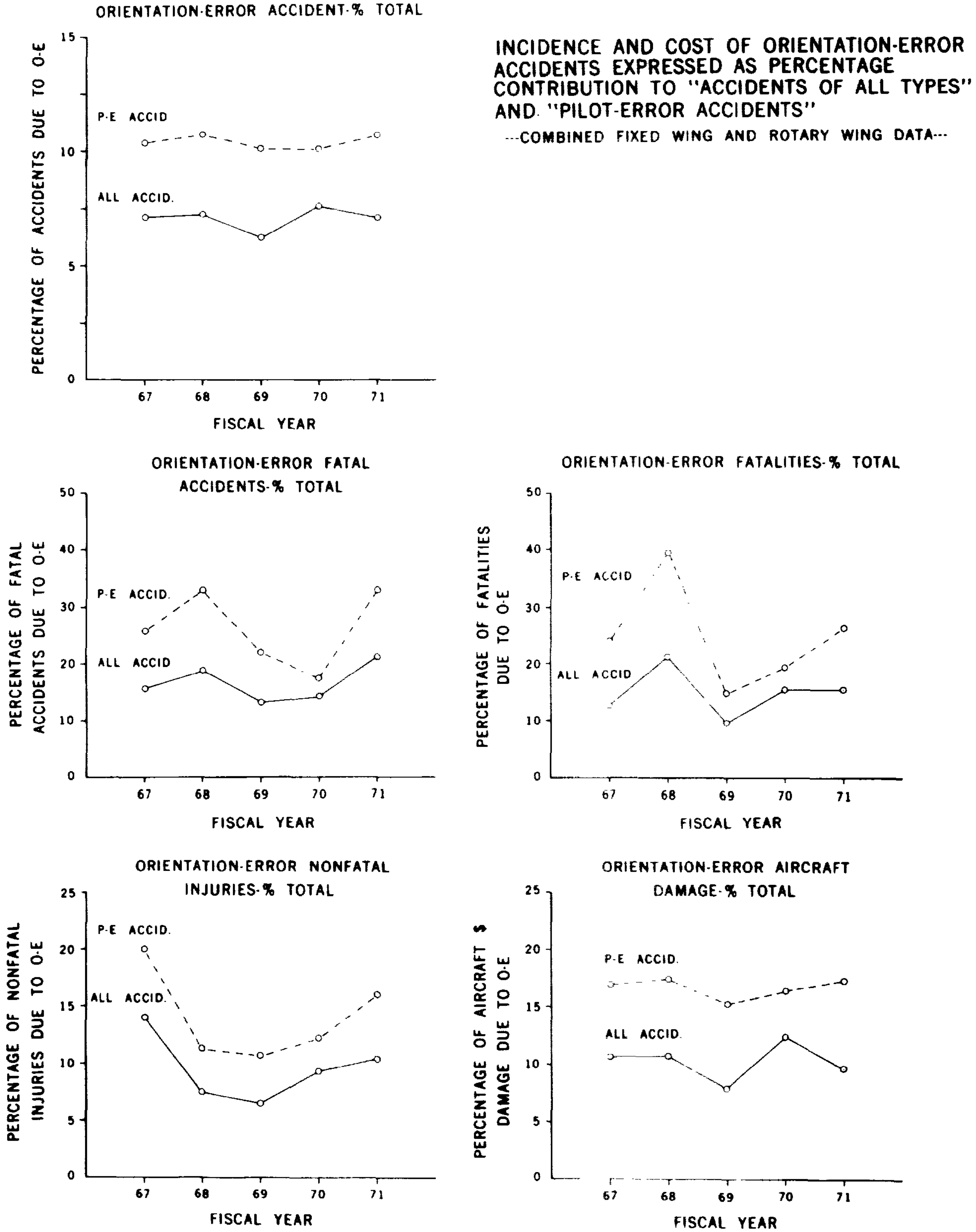

INCIDENCE AND COST OF ORIENTATION-ERROR ACCIDENTS EXPRESSED AS PERCENTAGE CONTRIBUTION TO "ACCIDENTS OF ALL TYPES" AND "PILOT-ERROR ACCIDENTS"
---COMBINED FIXED WING AND ROTARY WING DATA---
ORIENTATION-ERROR ACCIDENT-% TOTAL
PERCENTAGE OF ACCIDENTS DUE TO O-E
P-E ACCID
ALL ACCID.
15
10
5
0
67
68
69
70
71
FISCAL YEAR
ORIENTATION-ERROR FATAL ACCIDENTS-% TOTAL
PERCENTAGE OF FATAL ACCIDENTS DUE TO O-E
P-E ACCID.
ALL ACCID
50
40
30
20
10
0
67
68
69
70
71
FISCAL YEAR
ORIENTATION-ERROR FATALITIES-% TOTAL
PERCENTAGE OF FATALITIES DUE TO O-E
P-E ACCID
ALL ACCID
50
40
30
20
10
0
67
68
69
70
71
FISCAL YEAR
ORIENTATION-ERROR NONFATAL INJURIES-% TOTAL
PERCENTAGE OF NONFATAL INJURIES DUE TO O-E
P-E ACCID.
ALL ACCID.
25
20
15
10
5
0
67
68
69
70
71
FISCAL YEAR
ORIENTATION-ERROR AIRCRAFT DAMAGE-% TOTAL
PERCENTAGE OF AIRCRAFT $ DAMAGE DUE TO O-E
P-E ACCID.
ALL ACCID.
25
20
15
10
5
0
67
68
69
70
71
FISCAL YEAR

Figure 2.

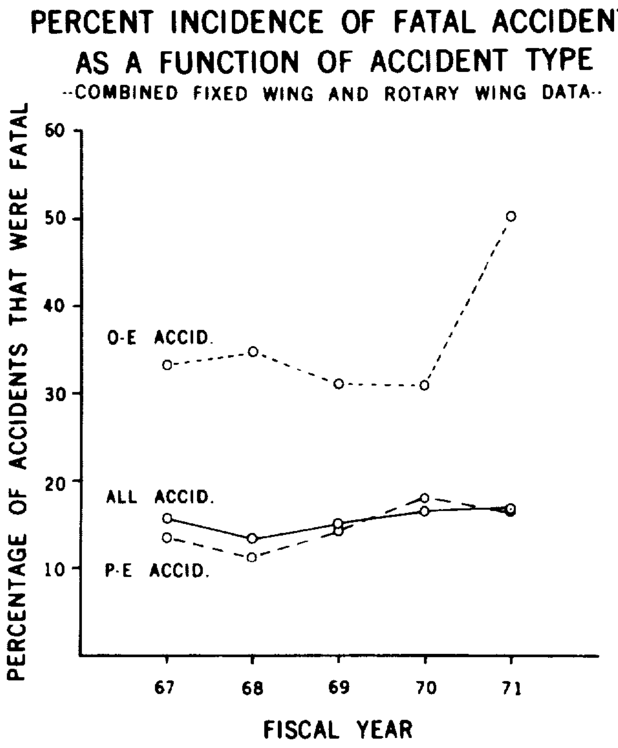


Figure 3.

THE HIGH INCIDENCE OF FATAL ORIENTATION-ERROR ACCIDENTS

Figure 3 is a year-by-year plot of the percentage incidence of fatal accidents that occurred in Army aircraft (RW and FW data combined) within the orientation-error accident, pilot-error accident, and all-accident data bases of the study. It is readily apparent that the fatal accident hazard of OE accidents is significantly greater than that of the two other accident classifications. Over the five-year study period, approximately 35.0 percent of the OE accidents were fatal; in no year did the fatal accident incidence fall below 30 percent. Of the total number of PE accidents, approximately 14.7 percent were fatal; for accidents of all types, 15.3 percent were fatal.

By considering only the RW components of the above data, it may be shown that approximately 35.0 percent of the OE accidents that occurred in RW aircraft were fatal, 15.0 percent of the PE accidents were fatal, and 15.4 percent of all accidents were fatal. For FW aircraft 42.3 percent of the OE accidents were fatal, 12.8 percent of the PE accidents were fatal, and 14.0 percent of all accidents were fatal. These data indicate that the fatal accident risk of orientation-error accidents was slightly higher for FW aircraft. (As stated previously, this comparison is limited by the relatively low N of the FW orientation-error accidents —— 26 total OE accidents, of which 11 were fatal.)

The high fatal accident risk of orientation-error as quantified by the data of this study is in general conformance with the previously referenced FW data. The findings of this study establish that a high risk exists also for RW aircraft operations.

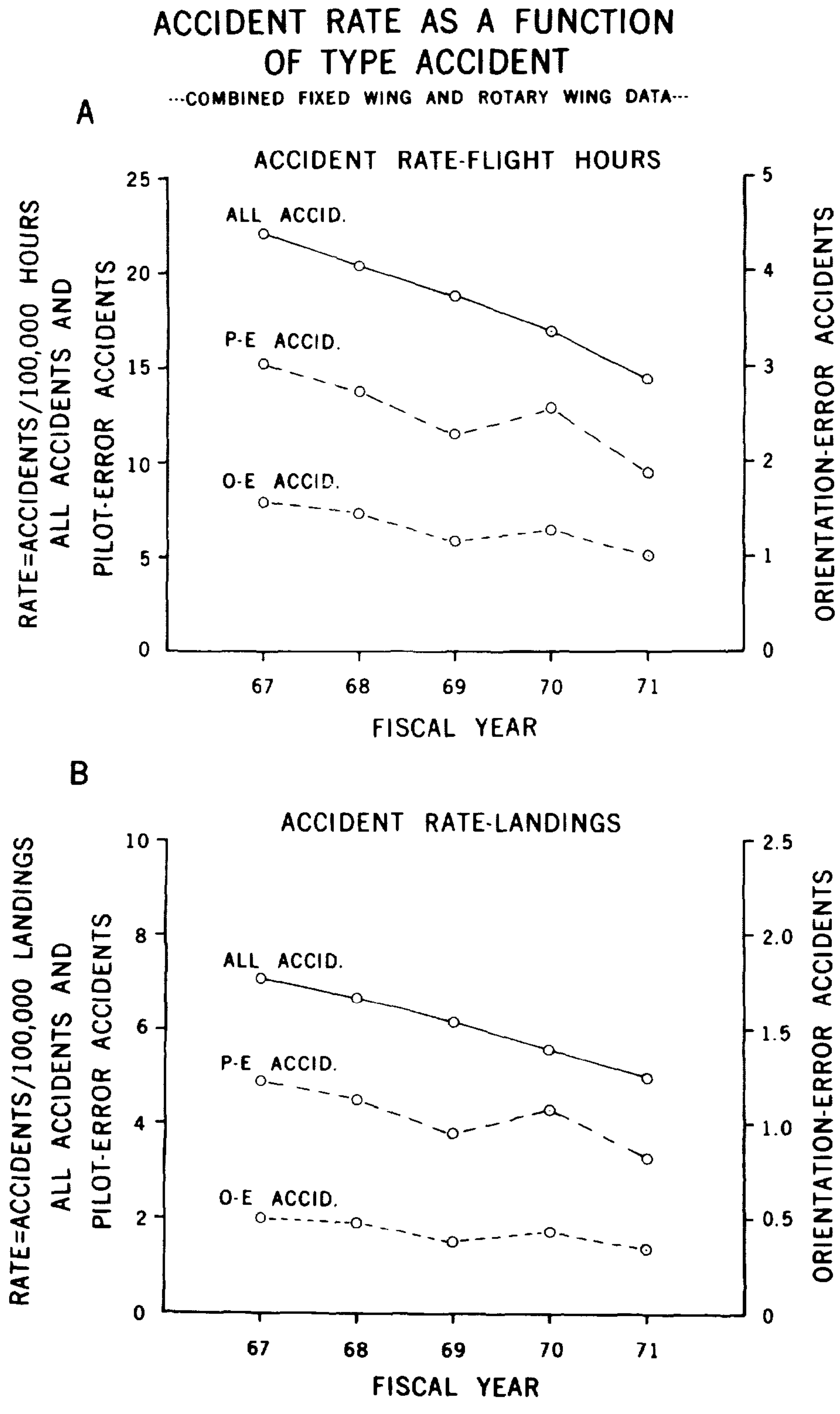
ACCIDENT RATE AS A FUNCTION OF TYPE ACCIDENT AND TYPE AIRCRAFT

In Figure 4 accident rate data based on 1) accidents per 100,000 flight hours and 2) accidents per 100,000 landings are presented for each of the three accident classifications on an individual-year basis. These combined FW and RW aircraft data indicate a general downward trend in accident rate over the study period with the least change occurring in the orientation-error classification. Mean accident rate data for the entire study period are listed in Table II as a function of type accident and type aircraft. Although it has not been past practice to present accident rate data on a stand-alone basis for orientation-error accidents, it is felt that these current data will be of value to future investigations that may be directed toward evaluating the progress made in reducing the spatial disorientation accident hazard.

As indicated in Table II, the mean OE accident rate figures for all aircraft were calculated as 1.28 accidents per 100,000 hours and 0.42 accidents per 100,000 landings. For RW aircraft the OE accident rate was approximately 2.6 times greater than the FW rate based on hours and 1.1 times greater than (nearly equal to) the FW rate based on landings. Examination of the PE and all-accident data of Table II indicates that the RW rates were 1.3 and 1.5 times greater, respectively, than the FW rates based on hours; but only 0.58 and 0.64 times the FW rates, respectively, based on landings. The lower RW accident rate based on landings is generally accepted as arising from the shorter-duration/multiple-hop nature of helicopter missions. The above data indicate, however, that the ratio of RW to FW accident rates is greatest for the orientation-error accident classification as compared to the other two classifications.

ACCIDENT RATE AS A FUNCTION OF LOCATION/MISSION

In Figure 5 combined RW and FW accident rate data, using both flight hours and landings as reference, are presented on an individual-year basis as a function of 1) accidents that occurred in Vietnam (VN), and 2) accidents that occurred elsewhere, primarily in the United States (US). Figures 5A and 5B pertain to accidents of all types, 5C and 5D to pilot-error accidents, and 5E and 5F to orientation-error accidents. Table III lists the ratio of the mean VN accident rate to the mean US accident rate over the study period for each of the three accident classifications and for each type of aircraft. All of these data provide a well-quantified description of the expected hazard of operations in a combat zone. For all aircraft, using hours as reference, the mean accident rate in VN was approximately 2.4 times greater than the mean rate in US for all accidents, 2.1 times greater for PE accidents, and 3.4 times greater for OE accidents. The landings-based rate data show an even greater cost of VN operations in that the VN/US accident rate ratio was 3.4 for all accidents, 2.9 for PE accidents, and 4.6 for OE accidents. (It should be noted very specifically that the data presented


ACCIDENT RATE AS A FUNCTION
OF TYPE ACCIDENT
---COMBINED FIXED WING AND ROTARY WING DATA---
A
ACCIDENT RATE-FLIGHT HOURS
RATE=ACCIDENTS/100,000 HOURS
ALL ACCIDENTS AND
PILOT-ERROR ACCIDENTS
ORIENTATION-ERROR ACCIDENTS
ALL ACCID.
P-E ACCID.
O-E ACCID.
25
20
15
10
5
0
5
4
3
2
1
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67
68
69
70
71
FISCAL YEAR
B
ACCIDENT RATE-LANDINGS
RATE=ACCIDENTS/100,000 LANDINGS
ALL ACCIDENTS AND
PILOT-ERROR ACCIDENTS
ORIENTATION-ERROR ACCIDENTS
ALL ACCID.
P-E ACCID.
O-E ACCID.
10
8
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67
68
69
70
71
FISCAL YEAR

Figure 4.

TABLE II.

Mean accident rate over the five-year study period as a function of type aircraft for the orientation-error, pilot-error, and all-accident classifications

	Accidents per 100,000 Hours			Accidents per 100,000 Landings		
	RW Acft	FW Acft	ALL Acft	RW Acft	FW Acft	ALL Acft
O-E Accidents	1.44	0.55	1.28	0.43	0.38	0.42
P-E Accidents	12.98	9.61	12.37	3.84	6.64	4.09
ALL Accidents	19.43	12.84	18.23	5.75	8.86	6.02

in this study pertain only to accidents and not to losses due to direct enemy action against the accident aircraft.) Although all three accident classifications clearly show the relatively high accident hazard of the combat-oriented missions in VN, orientation-error accidents were most affected. A review of the OE accident case histories presented previously (refs. 22-26) will document the complexity of many of the VN missions where orientation error occurred.

A comparison of the FW and RW accident rate data of Table III indicates that although both aircraft categories were affected by VN operations, the hazard was greatest for RW aircraft regardless of the type of accident and regardless of the type of rate reference. For both aircraft types the VN/US accident rate ratios were greatest for the orientation-error accident classification.

A last point concerning the effect of location on accident rate involves the relatively constant accident rate for accidents that occurred in locations other than VN for all three accident classifications, as shown by the Figure 5 data. These data indicate that the gradual decline in accident rate shown in Figure 4 (which pertains to all accidents regardless of location) derives in great part from the year-by-year reduction in the VN accident rate over the course of the study. It could be argued that the drop in the VN accident rate for all three accident classifications was due to a gradual decline in VN operations over the study. However, from 1967 through 1971 the flight hours flown in VN were approximately 3.6, 5.1, 6.1, 6.3, and 4.9 million hours, respectively, indicating maximal aircraft time utilization in the 1969-1970 period. More effective arguments would center on the increased experience and familiarity of the aviation teams in VN with the assigned missions, the gradual elimination of those extremely hazardous missions that offered minimal combat payoff, improvement in ground/air combat coordination, and a growing attention to the need for improving combat efficiency by reducing the number of aircraft lost due to accidents. Regardless of the actual reason for the decline in the VN accident rate over the study period, the Figure 5 data indicate that the rate reduction occurred across the board for all accident classifications. If the argument is allowed that the reduction was due in part to higher emphasis on accident prevention during the latter years of the study, then whatever

ACCIDENT RATE AS A FUNCTION OF LOCATION
--COMBINED FIXED WING AND ROTARY WING DATA--

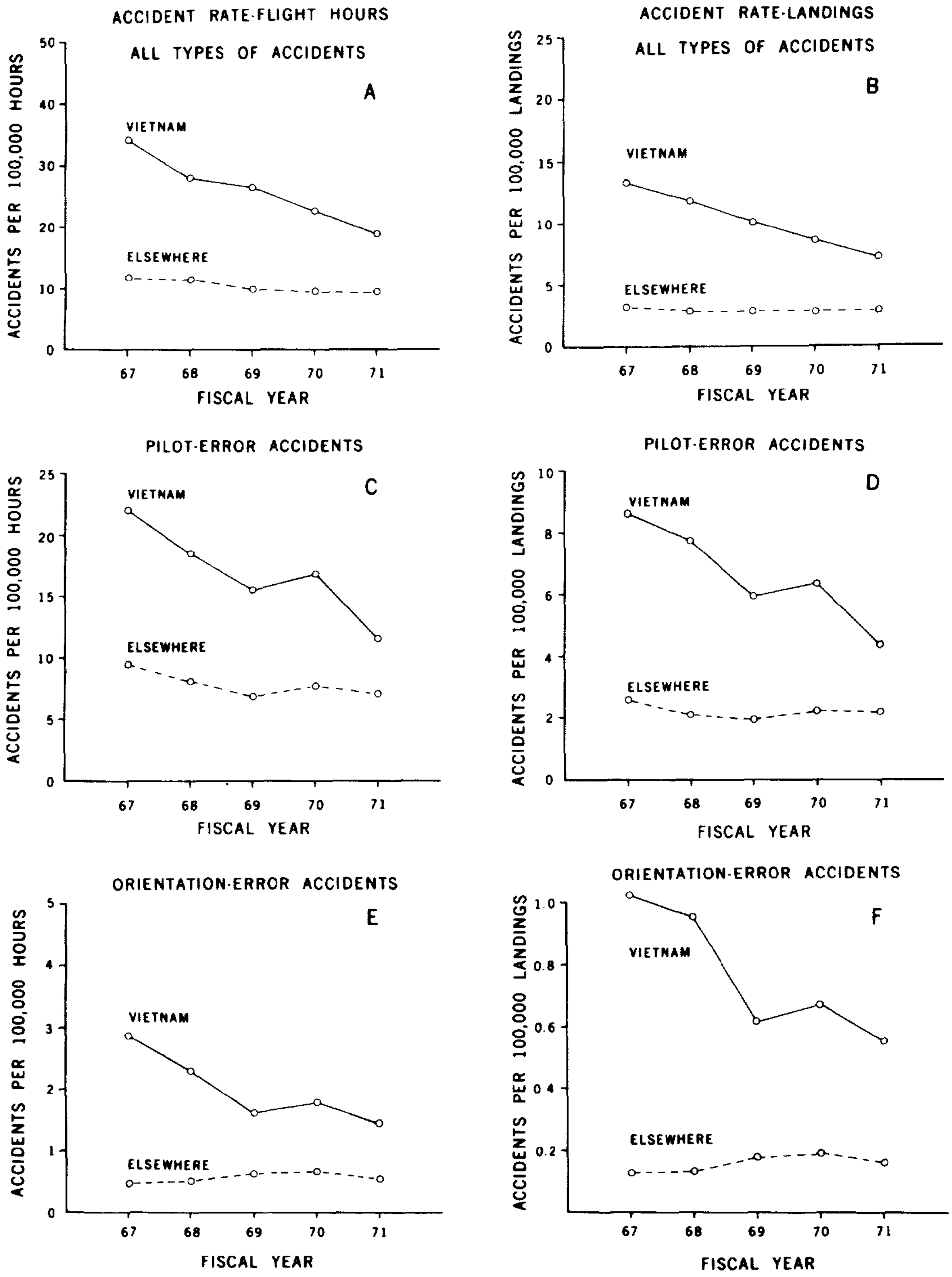

Figure 5.

TABLE III.

Ratio of mean accident rate in Vietnam to mean accident rate of accidents occurring elsewhere (primarily in the United States) as a function of type aircraft for the orientation-error, pilot-error, and all-accident classifications.

	VN/US Accident Ratio-Hours Reference			VN/US Accident Ratio-Landings Reference		
	RW Acft	FW Acft	ALL Acft	RW Acft	FW Acft	ALL Acft
O-E Accidents	3.5	1.6	3.4	4.9	3.6	4.6
P-E Accidents	2.3	1.2	2.1	3.2	2.7	2.9
ALL Accidents	2.7	1.3	2.4	3.7	2.9	3.4

measures were taken to reduce PE accidents also resulted in a reduction of OE accidents.

RESULTS AND DISCUSSION: UH-1 AIRCRAFT

Just as RW aircraft comprised the major portion of the Army aircraft inventory during the study period, the UH-1 helicopter comprised the major portion of the RW inventory. Because of the importance of this specific aircraft relative to the Army aviation mission, one phase of the longitudinal study was directed toward the separate acquisition of orientation-error accident statistics for only this aircraft (refs. 17-21). A summary of the incidence and cost data associated with the UH-1 is presented graphically in Figure 6 and tabulated, along with related pilot-error and all-accident data, in Table IV. The discussion format for these data follows that of the preceding section.

NUMERICAL INCIDENCE AND COST OF ORIENTATION-ERROR ACCIDENTS

During the course of the study, 223 major and minor UH-1 aircraft accidents were classified as involving orientation error. These accidents, 80 of which were fatal, accounted for 261 fatalities, 334 nonfatal injuries, and a total aircraft damage cost of nearly $38,000,000. Of the total number of orientation-error accidents that occurred in all RW aircraft, the UH-1 aircraft accounted for approximately 72 percent of the accidents, 75 percent of the fatal accidents, 84 percent of the fatalities, 80 percent of the nonfatal injuries, and 64 percent of the total RW aircraft damage costs. The mean data of Table IV indicate that on the average, the annual cost of orientation error in UH-1 aircraft was approximately 45 accidents, 16 fatal accidents, 52 fatal injuries, 67 nonfatal injuries, and $7,600,000 aircraft damage.

PERCENTAGE INCIDENCE AND COST OF ORIENTATION-ERROR ACCIDENTS

All-Accidents Measurement Reference

In terms of all accidents that occurred in UH-1 aircraft over the study period,

INCIDENCE AND COST OF ORIENTATION-ERROR ACCIDENTS
IN ARMY AVIATION OVER FY67-71 PERIOD

--- UH-1 AIRCRAFT (RW) ---

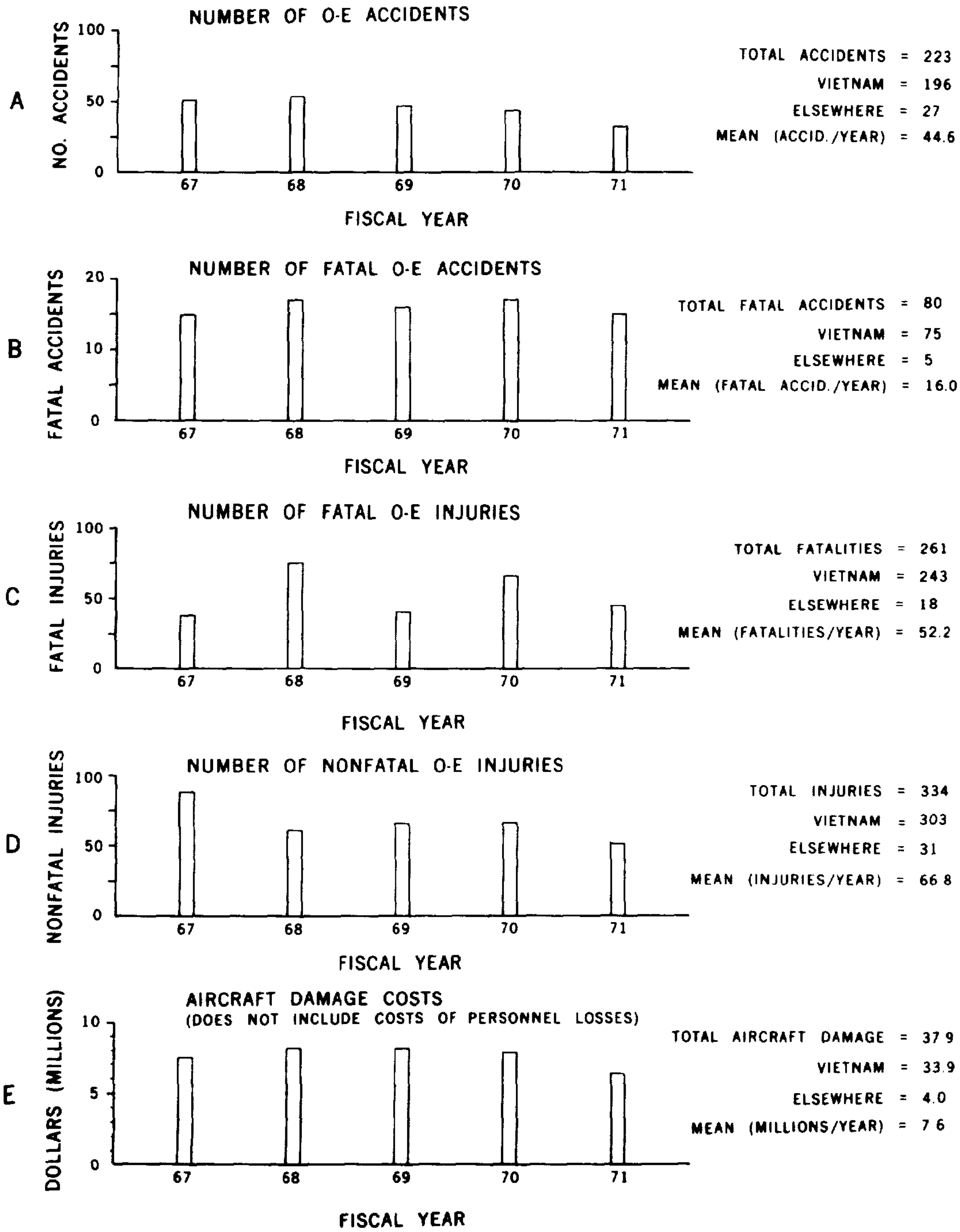

Figure 6.

TABLE IV

YEARLY INCIDENCE AND COST OF DIFFERENT TYPES OF ACCIDENTS THAT OCCURRED IN UH-1 AIRCRAFT OVER THE 5-YEAR STUDY PERIOD

ORIENTATION-ERROR ACCIDENTS

	1967	1968	1969	1970	1971	TOTAL	MEAN
Number of Major Accidents	44	53	44	43	31	215	43·0
Number of Minor Accidents	6	0	2	0	0	8	1·6
Total Number of Accidents	50	53	46	43	31	223	44·6
Accidents per 100,000 Hours	3·32	2·26	2·18	1·60	1·46	----	1·99
Accidents per 100,000 Landings	0·99	0·74	0·54	0·47	0·44	----	0·61
Number of Fatal Accidents	15	17	16	17	15	80	16·0
Number of Fatal Injuries	38	74	39	66	44	261	52·2
Number of Nonfatal Injuries	88	60	67	67	52	334	66·8
Total Aircraft Damage-Dollars	7,542,177	8,224,607	8,130,297	7,706,191	6,337,446	37,940,718	7,588,144

PILOT-ERROR ACCIDENTS

	1967	1968	1969	1970	1971	TOTAL	MEAN
Number of Major Accidents	281	341	286	362	174	1444	288·8
Number of Minor Accidents	28	17	35	17	12	109	21·8
Total Number of Accidents	309	358	321	379	186	1553	310·6
Accidents per 100,000 Hours	20·52	15·24	12·53	14·10	8·76	----	13·83
Accidents per 100,000 Landings	6·10	5·01	3·74	4·18	2·66	----	4·22
Number of Fatal Accidents	52	51	49	82	36	270	54·0
Number of Fatal Injuries	137	175	163	281	109	865	173·0
Number of Nonfatal Injuries	366	499	236	526	271	1898	379·6
Total Aircraft Damage-Dollars	40,503,684	48,939,669	45,434,000	59,469,113	28,888,732	223,235,198	44,647,040

ACCIDENTS OF ALL TYPES

	1967	1968	1969	1970	1971	TOTAL	MEAN
Number of Major Accidents	411	537	504	461	285	2198	439·6
Number of Minor Accidents	44	28	41	21	14	148	29·6
Total Number of Accidents	455	565	545	482	299	2346	469·2
Accidents per 100,000 Hours	30·22	24·05	21·28	17·94	14·09	----	20·90
Accidents per 100,000 Landings	8·98	7·91	6·35	5·32	4·28	----	6·37
Number of Fatal Accidents	85	85	81	102	54	407	81·4
Number of Fatal Injuries	260	313	281	360	180	1394	278·8
Number of Nonfatal Injuries	533	737	699	682	398	3049	609·8
Total Aircraft Damage-Dollars	62,644,100	77,721,403	82,379,000	75,000,046	47,375,401	345,119,950	69,023,990

orientation-error accidents accounted for approximately 9.5 percent of the total number of accidents, 19.7 percent of the total number of fatal accidents, 18.7 percent of the total number of fatalities, 11.0 percent of the total number of nonfatal injuries, and 11.0 percent of the total UH-1 aircraft damage costs. The year-to-year variations in these data are plotted in solid outline in Figure 7. Comparison of these data to the equivalent data for all RW aircraft indicates that the percentage contribution of orientation-error accidents to the over-all accident statistics was moderately greater for the UH-1 element of the helicopter inventory.

Pilot-Error Accident Measurement Reference

With reference to all pilot-error accidents that occurred in the UH-1 aircraft over the study period, orientation error accounted for approximately 14.4 percent of the total number of PE accidents, 29.6 percent of the total number of fatal PE accidents, 30.2 percent of the PE fatalities, 17.6 percent of the PE nonfatal injuries, and 17.0 percent of the total UH-1 aircraft damage costs due to PE. (See Figure 7 — dashed outline curves.) Again, as compared to the equivalent data for all RW aircraft, the percentage contribution of orientation-error accidents to the pilot-error accident statistics was moderately greater for the UH-1 element of the inventory.

THE HIGH INCIDENCE OF FATAL ORIENTATION-ERROR ACCIDENTS

Figure 8 is a plot of the percentage incidence of fatal accidents that occurred in Army UH-1 aircraft as a function of the three accident classifications of the study. Over the study period, the mean percentage incidence of fatal accidents was approximately 35.8 percent for OE accidents, 17.4 percent for PE accidents, and 17.3 percent for accidents of all types. Again, for the UH-1 aircraft in this case definitive evidence is available to show the high risk of orientation-error accidents in RW aircraft. It should be noted that the absolute number of fatal OE accidents that occurred in a given year remained relatively fixed over the study period while the total number of OE accidents (fatal and nonfatal) showed a slight decline. This relationship accounts for the upward slope of the OE data presented in Figure 8.

ACCIDENT RATE AS A FUNCTION OF TYPE ACCIDENT

Figure 9 is a plot of UH-1 aircraft accident rate data for the three accident classifications, using both hours (top) and landings (bottom) as measurement references. For orientation-error accidents the mean accident rates were approximately 1.99 accidents per 100,000 hours and 0.61 accidents per 100,000 landings. Equivalent rate figures for PE accidents were 13.83 and 4.22; and for all UH-1 accidents regardless of cause, 20.9 and 6.37, respectively. For all three accident classifications, the UH-1 accident rates exceeded the corresponding rates for the entire RW aircraft inventory.

ACCIDENT RATE AS A FUNCTION OF LOCATION/MISSION

In Figure 10 accident rate data for the UH-1 aircraft, using both hours and

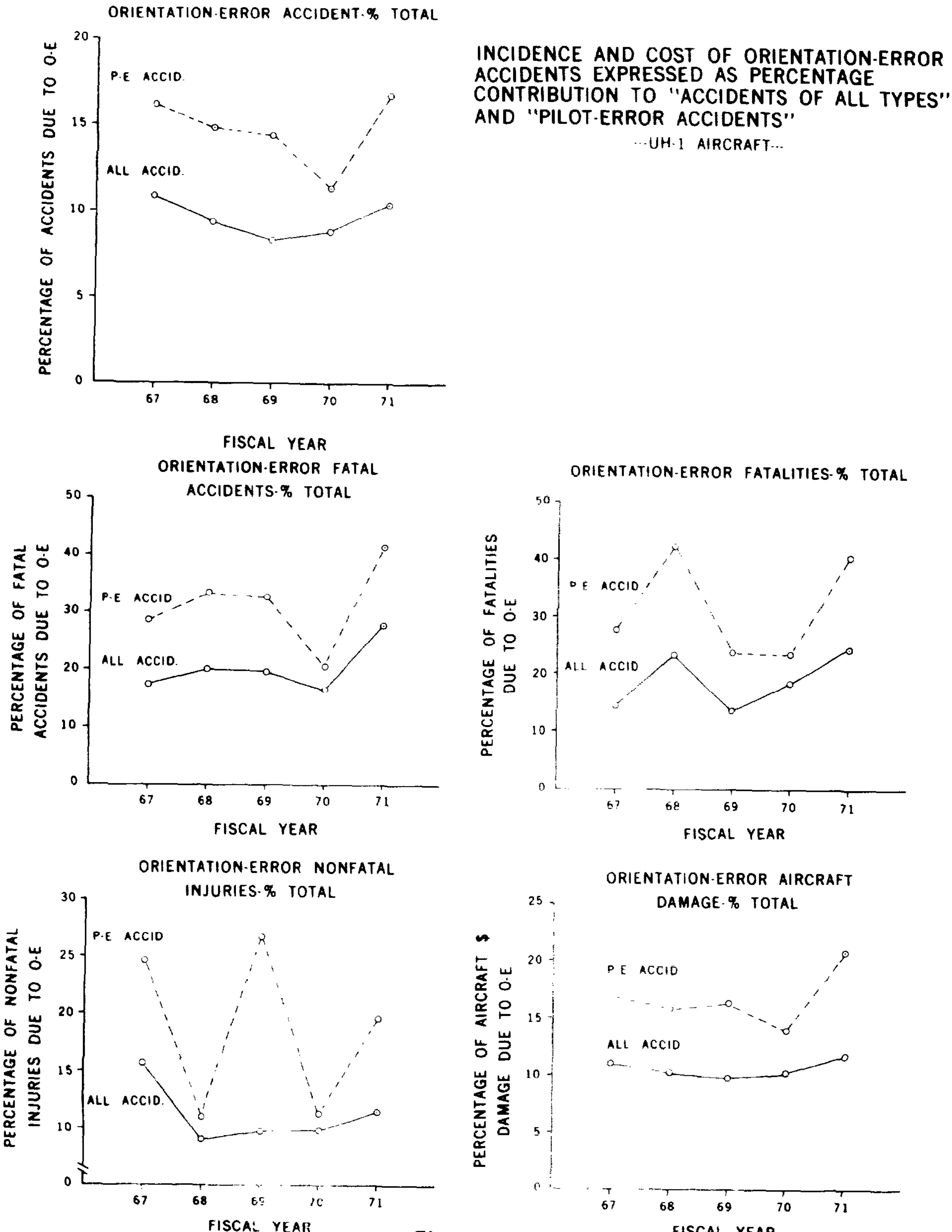
INCIDENCE AND COST OF ORIENTATION-ERROR ACCIDENTS EXPRESSED AS PERCENTAGE CONTRIBUTION TO "ACCIDENTS OF ALL TYPES" AND "PILOT-ERROR ACCIDENTS"
---UH-1 AIRCRAFT---
ORIENTATION-ERROR ACCIDENT-% TOTAL
PERCENTAGE OF ACCIDENTS DUE TO O-E
P-E ACCID.
ALL ACCID.
FISCAL YEAR
ORIENTATION-ERROR FATAL ACCIDENTS-% TOTAL
PERCENTAGE OF FATAL ACCIDENTS DUE TO O-E
P-E ACCID
ALL ACCID.
FISCAL YEAR
ORIENTATION-ERROR FATALITIES-% TOTAL
PERCENTAGE OF FATALITIES DUE TO O-E
P-E ACCID
ALL ACCID
FISCAL YEAR
ORIENTATION-ERROR NONFATAL INJURIES-% TOTAL
PERCENTAGE OF NONFATAL INJURIES DUE TO O-E
P-E ACCID
ALL ACCID.
FISCAL YEAR
ORIENTATION-ERROR AIRCRAFT DAMAGE-% TOTAL
PERCENTAGE OF AIRCRAFT $ DAMAGE DUE TO O-E
P-E ACCID
ALL ACCID
FISCAL YEAR

Figure 7.

PERCENT INCIDENCE OF FATAL ACCIDENTS
AS A FUNCTION OF ACCIDENT TYPE

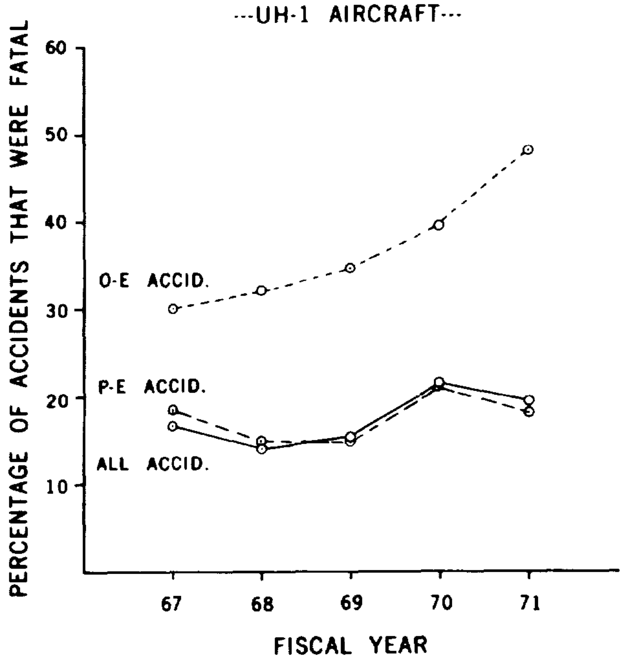

Figure 8.

and landings as reference, are plotted on a year-to-year basis as a function of accidents that occurred in Vietnam and accidents that occurred elsewhere, primarily in the United States. The high hazard of the operations that occurred in VN is obvious. Over the study period, the mean VN accident rate, using hours as reference, was 2.7 times greater than the US rate for OE accidents, 2.2 times greater for PE accidents, and 2.4 times greater for accidents of all types. Using landings as reference, the mean VN accident rate was 3.4 times greater than the US rate for OE accidents, 2.8 times greater for PE accidents, and 3.1 times greater for accidents of all types. When equivalent rate figures were calculated for only fatal accidents, the VN rate was 5.6, 3.7, and 3.0 times greater, using hours as reference, and 7.1, 4.7, and 4.8 times greater, using landings as reference, for the OE, PE, and all-accident classifications, respectively. As with the RW and FW data of the previous section, all three accident classifications for the UH-1 aircraft show the higher accident potential of operations in a combat theater with orientation-error accidents most affected. Similarly, all of the Figure 10 data show a significant reduction in the VN accident rate over the study period. In the case of orientation-error accidents, the ratio between the VN and US accidents remained relatively constant over the last three years of the study.

ACCIDENT RATE AS A FUNCTION OF TYPE ACCIDENT

---UH-1 AIRCRAFT---

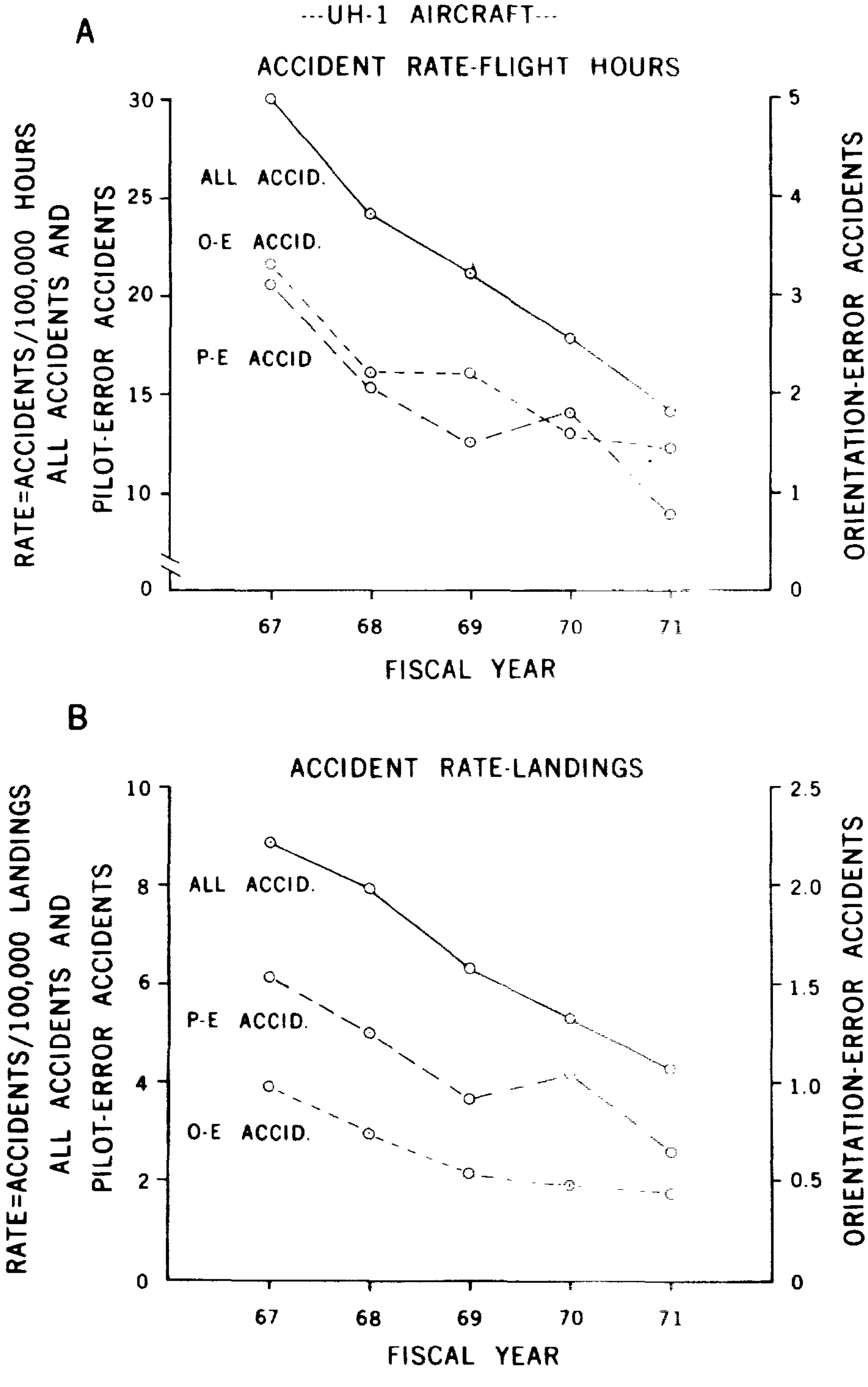

Figure 9.

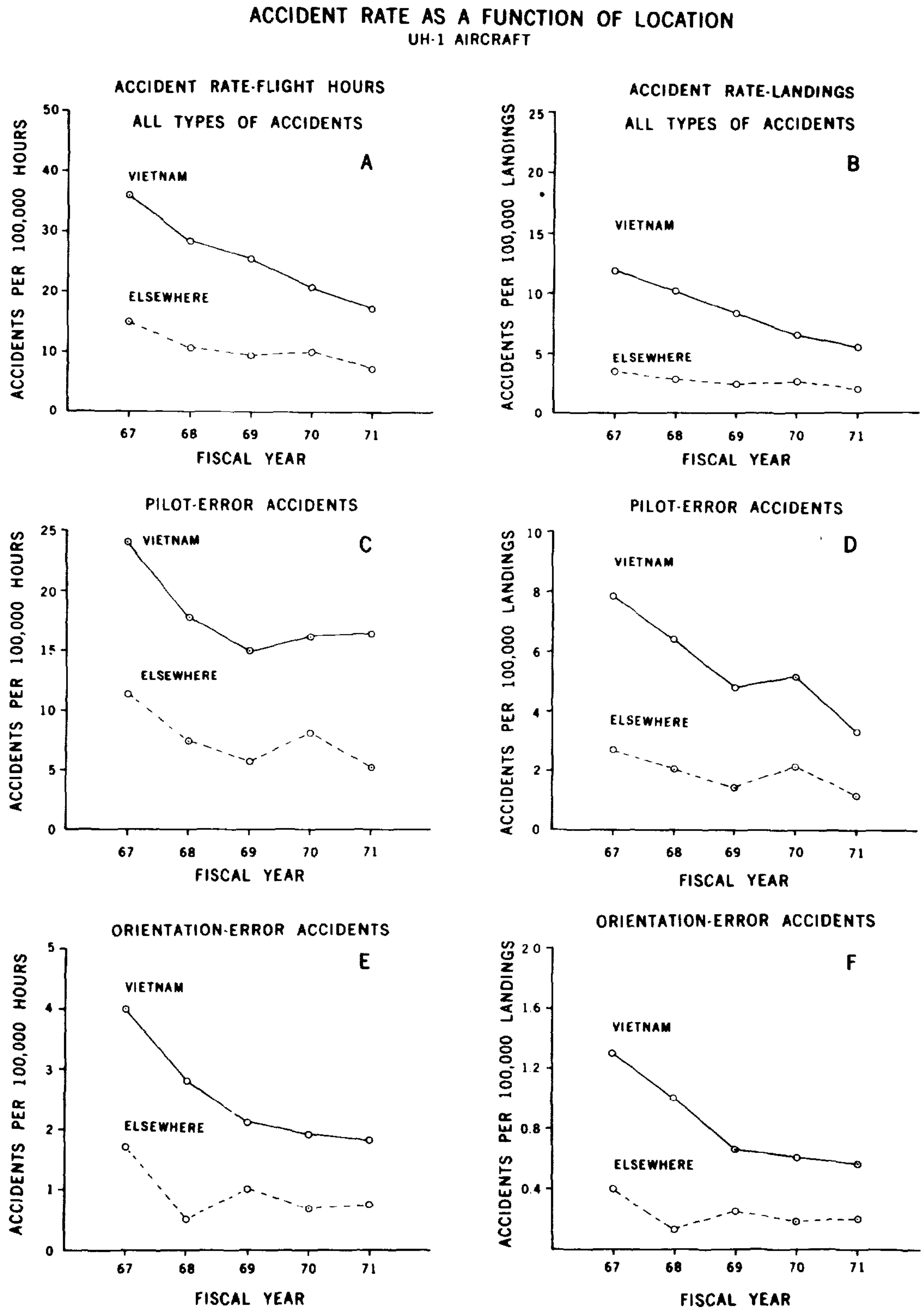
ACCIDENT RATE AS A FUNCTION OF LOCATION
UH-1 AIRCRAFT
ACCIDENT RATE-FLIGHT HOURS
ALL TYPES OF ACCIDENTS
A
VIETNAM
ELSEWHERE
ACCIDENTS PER 100,000 HOURS
FISCAL YEAR
ACCIDENT RATE-LANDINGS
ALL TYPES OF ACCIDENTS
B
VIETNAM
ELSEWHERE
ACCIDENTS PER 100,000 LANDINGS
FISCAL YEAR
PILOT-ERROR ACCIDENTS
C
VIETNAM
ELSEWHERE
ACCIDENTS PER 100,000 HOURS
FISCAL YEAR
PILOT-ERROR ACCIDENTS
D
VIETNAM
ELSEWHERE
ACCIDENTS PER 100,000 LANDINGS
FISCAL YEAR
ORIENTATION-ERROR ACCIDENTS
E
VIETNAM
ELSEWHERE
ACCIDENTS PER 100,000 HOURS
FISCAL YEAR
ORIENTATION-ERROR ACCIDENTS
F
VIETNAM
ELSEWHERE
ACCIDENTS PER 100,000 LANDINGS
FISCAL YEAR

Figure 10.

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APPENDIX A

Accident Statistics for All-Accident and Pilot-Error Accident Categories

TABLE A1

YEARLY INCIDENCE AND COST OF ACCIDENTS OF ALL TYPES THAT OCCURRED IN ARMY AIRCRAFT OVER THE 5-YEAR STUDY PERIOD

ALL AIRCRAFT	1967	1968	1969	1970	1971	TOTAL	MEAN
Number of Major Accidents	736	985	1075	1015	679	4490	898·0
Number of Minor Accidents	66	57	68	42	29	262	52·4
Total Number of Accidents	802	1042	1143	1057	708	4752	950·4
Accidents per 100,000 Hours	22·13	20·33	18·74	16·85	14·34	-----	18·23
Accidents per 100,000 Landings	7·04	6·64	6·16	5·60	4·92	-----	6·02
Number of Fatal Accidents	124	138	169	176	119	726	145·2
Number of Fatal Injuries	362	429	521	518	324	2154	430·8
Number of Nonfatal Injuries	753	999	1217	1119	647	4735	947·0
Total Aircraft Damage-Dollars	95,737,699	116,237,672	149,271,000	156,742,631	117,556,029	635,545,031	127,109,006

ROTARY WING AIRCRAFT	1967	1968	1969	1970	1971	TOTAL	MEAN
Number of Major Accidents	602	846	976	913	601	3938	787·6
Number of Minor Accidents	57	46	57	29	20	209	41·8
Total Number of Accidents	659	892	1033	942	621	4147	829·4
Accidents per 100,000 Hours	23·46	21·68	20·50	17·88	15·08	-----	19·43
Accidents per 100,000 Landings	6·45	6·31	6·04	5·41	4·70	-----	5·75
Number of Fatal Accidents	104	117	154	164	102	641	128·2
Number of Fatal Injuries	315	381	489	494	287	1966	393·2
Number of Nonfatal Injuries	661	940	1152	1075	619	4447	889·4
Total Aircraft Damage-Dollars	81,590,044	101,632,366	142,091,000	145,620,195	104,881,877	575,815,482	115,163,096

FIXED WING AIRCRAFT	1967	1968	1969	1970	1971	TOTAL	MEAN
Number of Major Accidents	134	139	99	102	78	552	110·4
Number of Minor Accidents	9	11	11	13	9	53	10·6
Total Number of Accidents	143	150	110	115	87	605	121·0
Accidents per 100,000 Hours	17·52	14·85	10·36	11·43	10·63	-----	12·84
Accidents per 100,000 Landings	12·14	9·64	7·58	7·95	7·28	-----	8·86
Number of Fatal Accidents	20	21	15	12	17	85	17·0
Number of Fatal Injuries	47	48	32	24	37	188	37·6
Number of Nonfatal Injuries	92	59	65	44	28	288	57·6
Total Aircraft Damage-Dollars	14,147,655	14,605,306	7,180,000	11,122,436	12,674,152	59,729,549	11,945,910

TABLE A2

YEARLY INCIDENCE AND COST OF PILOT-ERROR ACCIDENTS THAT OCCURRED IN ARMY AIRCRAFT OVER THE 5-YEAR STUDY PERIOD

ALL AIRCRAFT

	1967	1968	1969	1970	1971	TOTAL	MEAN
Number of Major Accidents	510	667	649	774	442	3042	608·4
Number of Minor Accidents	42	35	52	31	22	182	36·4
Total Number of Accidents	552	702	701	805	464	3224	644·8
Accidents per 100,000 Hours	15·23	13·70	11·49	12·83	9·40	-----	12·37
Accidents per 100,000 Landings	4·84	4·47	3·78	4·27	3·22	-----	4·09
Number of Fatal Accidents	74	79	100	144	76	473	94·5
Number of Fatal Injuries	189	232	346	413	192	1372	274·4
Number of Nonfatal Injuries	525	665	741	856	423	3210	642·0
Total Aircraft Damage-Dollars	60,386,405	71,522,704	78,897,000	118,292,367	66,101,642	395,200,118	79,040,023

ROTARY WING AIRCRAFT

	1967	1968	1969	1970	1971	TOTAL	MEAN
Number of Major Accidents	409	562	578	687	386	2622	524·4
Number of Minor Accidents	37	29	45	21	17	149	29·8
Total Number of Accidents	446	591	623	708	403	2771	554·2
Accidents per 100,000 Hours	15·88	14·36	12·36	13·44	9·79	-----	12·98
Accidents per 100,000 Landings	4·36	4·18	3·64	4·06	3·05	-----	3·84
Number of Fatal Accidents	61	65	91	132	66	415	83·0
Number of Fatal Injuries	154	202	327	389	172	1244	248·8
Number of Nonfatal Injuries	456	620	689	817	401	2983	596·6
Total Aircraft Damage-Dollars	50,993,453	62,561,826	74,045,000	108,668,309	59,841,340	356,109,928	71,221,986

FIXED WING AIRCRAFT

	1967	1968	1969	1970	1971	TOTAL	MEAN
Number of Major Accidents	101	105	71	87	56	420	84·0
Number of Minor Accidents	5	6	7	10	5	33	6·6
Total Number of Accidents	106	111	78	97	61	453	90·6
Accidents per 100,000 Hours	12·99	10·99	7·34	9·64	7·45	-----	9·61
Accidents per 100,000 Landings	9·00	7·13	5·37	6·71	5·11	-----	6·64
Number of Fatal Accidents	13	14	9	12	10	58	11·6
Number of Fatal Injuries	35	30	19	24	20	128	25·6
Number of Nonfatal Injuries	69	45	52	39	22	227	45·4
Total Aircraft Damage-Dollars	9,392,952	8,960,878	4,852,000	9,624,058	6,260,302	39,090,190	7,818,038