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HELICOPTER CRASH SURVIVAL AT SEA- UNITED STATES NAVY/MARINE CORPS EXPERIENCE 1977-1990

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SUMMARY

This paper examines the United States Navy/Marine Corps' (USN) experience with helicopter Class A over water mishaps for the period from 1977 to 1990. There were 137 helicopter Class A flight mishaps over water during this period with an overall survival rate of 83% in survivable water crashes. During this period, the USN developed several programs to improve survivability. The helicopter water survival training device (WSTD or 9-D-5 device) was instituted in 1982. The helicopter emergency escape device system (HEEDS) and the helicopter emergency lighting system (HEELS) were implemented in 1987.

This study attempts to answer the question whether or not these programs have, in fact, improved survival since their implementation. In addition, the study reviews the types of operational problems encountered with these devices. The results indicate that the WSTD and HEEDS may have contributed to the statistically significant improved survival seen among Navy aircrew in night crashes. They may have also contributed to the improvement (not statistically significant) in survival among passengers in night crashes. The data were inconclusive with respect to the effects of HEELS because of its not being implemented throughout the fleet. Operational problems with these devices were minor and the benefits of each program far outweigh any risks. In fact, in night crashes aircrew had significantly higher likelihood of survival than passengers who were essentially untrained occupants. Other factors, in addition to the devices studied, may have also affected survival probabilities.

1 INTRODUCTION

Survivability in aircraft mishaps is usually a function of impact force magnitude and post crash environmental factors. Helicopter crash impact forces are often significantly less than fixed wing aircraft. As a result, a substantial portion of helicopter impacts are potentially survivable. However, when reduced impact forces are combined with water entry, the post crash environment presents unique challenges to the survivors. Crew and passenger escape are related to a multiplicity of factors, especially the actual egress from the aircraft.

Escape may be hampered by the sheer bulk of equipment worn, by problems in releasing restraint systems, or by difficulty in or inability to release or open escape hatches or windows. The individual crew member or passenger may be unable to reach emergency exits due to obstructions, equipment hang-up, unusual aircraft attitude, or personal injuries. Indeed, survivors may become trapped in

the aircraft. Although these factors are not unique to the water, they are certainly magnified at sea. Impact at sea is associated with the additional problem of an immediate in-rush of water. It may be dark, even in the day-time and it is frequently cold. The survivor will often experience confusion and disorientation. This may be compounded by injuries sustained during the initial dissipation of crash energy. He or she may be dazed, injured or rendered unconscious. There may be problems with fire, smoke, or fuel, although these are infrequent complications at sea. All of these problems have been well documented by other investigators (Refs 1 & 2).

During the past decade, the USN has implemented several programs in an attempt to reduce the overall mortality and morbidity associated with helicopter over water crashes. In 1981 the USN initiated a multi-place helicopter water ditching training program using the 9-D-5 Water Survival Training Device, the so-called "helo-dunker" (WSTD). The WSTD exposes aircrew to a series of simulated helicopter water impact scenarios and teaches the skills necessary for successful egress.

In 1987 the USN introduced the Helicopter Emergency Egress Device System (HEEDS) fleet-wide. This is an emergency breathing system that gives the aircrewman up to three minutes of air during the critical post-impact period. When one considers the rapidity with which most helicopters sink after water crashes, three minutes may make all the difference.

Also, in 1987 the USN began retrofitting its aviation fleet with the Helicopter Emergency Egress Lighting System (HEELS). This system is actuated at the time of impact or shortly thereafter by contact with water. It is strategically placed to indicate the route to and location of the main emergency exit.

The USN developed these systems as an integrated package to address the most pressing problems identified in helicopter water impacts. The WSTD would reduce the degree of panic, confusion and disorientation during attempted escape, HEEDS would provide sufficient time to reach the exit and HEELS would "light the way."

This study attempted to answer two questions. First, have these survival interventions (i.e., the WSTD, HEEDS, and HEELS) reduced the mortality/morbidity rates from over water helicopter crashes? Second, what kinds of problems have arisen and been documented in using these systems?

2 METHODS

The analysis was restricted to helicopter data for 1977-1990. For baseline comparison, we initially determined the total number of over land and over water helicopter Class A flight mishaps and their corresponding survival rates for the period in question (1977-1990). A Class A flight mishap is defined as one in which a naval aircraft was destroyed or the cost was over one million dollars of damage or there was loss of life or permanent total disability. Survival rates were computed both for Naval Aviation as a whole (Navy and Marine Corps) and for the individual services.

Over water helicopter crash data were then separated into three time periods to note the introduction of training modalities to be examined. Data were examined for 1977 through 1981 (P1), prior to introduction of the programs in question, for 1982 through 1986 (P2), after full implementation of the 9-D-5 trainer and for 1987 through 1990 (P3), after full implementation of the HEEDS program. No such evaluation was possible for HEELS, since the program has yet to be implemented fleet-wide. Only the Navy's H-60's and the Marine Corps H-46's have been completely

refitted with HEELS. All other Navy and Marine Corps helicopter types remain in some stage of HEELS retrofit.

The narrative of each over water mishap was examined to determine the problems, if any, created by each of the above safety interventions. Specific data on HEEDS were available in the Naval Safety Center Data Base. Data on operational problems encountered with HEELS were also available in the Data Base. For the 9-D-5 trainer, reports were analyzed from the Water Survival Training Model Manager located at the Naval Schools Command (Ref 3). The data were then converted into incidence of problems per 100,000 training evolutions. Finally, we applied statistical tests to determine if survival probabilities changed significantly across the time periods. We also compared United States Navy/Marine Corps over water statistics for differences in survival likelihoods.

3 RESULTS

During 1977-1990 there were 268 helicopter Class A flight mishaps, 131 over land and 137 over water. There were 721 occupants in the over land mishaps. Of these, 64% survived. The survivors included 67% of the 468 aircrew and 59% of the 253 passengers. The over water mishaps involved 638 occupants. The survivors numbered 70%, which consisted of 72% of the 499 aircrew and 60% of the 139 passengers.

The 137 over water crashes, which involved 138 occupied aircraft, included 115 survivable aircraft. A survivable aircraft is one in which at least one person survived. There were 537 occupants in these survivable aircraft. Of these, 83% survived. The survivors included 86% of the 418 aircrew and 71% of the 119 passengers.

Table I summarizes the results of the study of all survivable over water Class A helicopter flight mishaps. Statistical tests of significance were performed to test the hypothesis (Ho) that survival probability was independent of time against the hypothesis (H1) that survival probability and time were dependent. Ho was rejected in this analysis and results were defined to be "statistically significant" if the descriptive significance level, p, was less than .10. Tests were performed first for survivable over water crashes with time divided into 1977-1981 (P1), 1982-1986 (P2), and 1987-1990 (P3). The tests were performed on statistics stratified by aircrew and passengers, for Navy/Marine Corps combined, for Navy and Marine Corps separately, and for day versus night.

The stratifications were essential because of mission, aircraft, and policy differences between the services. The Marine Corps helicopter fleet consists primarily of the H-1, H-3, H-46, and H-53, while the Navy flies the H-1, H-2, H-3, H-46, H-53, H-57, H-58, and H-60. Throughout 1977-1990, the Navy has forbidden passengers on night helicopter operations. The Marine Corps' policy was the same until 1982 when amphibious missions required transporting troops ("passengers") under the "cloak of darkness."

Referring to Table I, there were statistically significant relationships between survival probability in Navy night as well as Marine Corps day over water survivable crashes and time period. Aircrew survival probabilities in Navy night crashes significantly increased from 79% (31 of 39) to 85% (52 of 61) to 94% (31 of 33) during P1, P2, and P3 respectively. However, both Marine Corps aircrew and passenger day crash survival probabilities significantly decreased from P1 to P2. There were no Marine Corps over water survivable day crashes during P3. The Marine Corps aircrew

day survival probabilities during P1 and P2 were 92% (24 of 26) and 67% (6 of 9) respectively. The Marine Corps passenger day survival probabilities during P1 and P2 were 100% (10 of 10) and 67% (12 of 18) respectively.

Statistical tests were also performed on over water survivable crash data across the 1977-1990 period where Ho: Survival probability was independent of (a) day, night; (b) aircrew, passenger; (c) Navy, Marine Corps against H1: Survival probability and (a); (b); (c) are dependent. Specific statistically significant relationships were observed. Both aircrew and passenger survival probabilities were significantly higher in day crashes than in night crashes for the Navy/Marine Corps combined (90%-234 of 260 vs 80%-127 of 158 for aircrew: day vs night and 88%-73 of 83 vs 31%-11 of 36 for passengers: day vs night). The differences were particularly large in the Marine Corps (86%-30 of 35 vs 52%-13 of 25 for aircrew: day vs night and 79%-22 of 28 vs 31%-11 of 35 for passenger: day vs night). Aircrew were also significantly more likely than passengers to survive night crashes Navy/Marine Corps combined (80%-127 of 158 vs 31%-11 of 36).

Comparisons between Navy and Marine Corps over water survivable Class A flight mishaps show that occupants of Navy aircraft were significantly more likely to survive than occupants of Marine Corps aircraft regardless if day or night or aircrew or passenger (89%-369 of 414 occupants in Navy aircraft survived while 62%-76 of 123 occupants in Marine Corps aircraft survived).

Statistical analysis of all Navy/Marine Corps Class A flight mishaps, survivable and non-survivable combined, showed that the probability of survival in over land crashes did not change significantly during P1, P2, and P3 for either aircrew or passengers (66%-153 of 232, 76%-91 of 120, 61%-71 of 116 for aircrew; 59%-53 of 90, 55%-45 of 82, 63%-51 of 81 for passengers). However, aircrew survival probability significantly declined in over water crashes with a larger decrease occurring in P3 over P1 and P2 (76%-123 of 162, 78%-155 of 198, 60%-83 of 139 for P1, P2, and P3 respectively). The passenger survival probabilities in over water crashes decreased after P1, but the decreases were not statistically significant (77%-20 of 26, 50%-34 of 68, 67%-30 of 45 for P1, P2, and P3 respectively). Finally, the probability of aircrew surviving an over water crash (72%-361 of 499) was significantly greater than surviving an over land crash (67%-315 of 468). The difference for passengers (60%-84 of 139 over water vs 59%-149 of 253 over land) was not statistically significant.

The p values throughout the analysis must be interpreted in view of the dependency of the data sets and the performance of multiple statistical tests.

Review of narratives of all over water crashes in which HEEDS was a factor in the egress phase of the mishap indicated 25 "saves." A "save" was defined as an individual who perceived that he or she would not have survived without the use of HEEDS. This was determined by review of survivor statements made to investigation boards.

Finally, there were problems reported during 9-D-5 training and with operational use of both HEEDS and HEELS. Since 1981, there has been one death reported related to 9-D-5 training. For the one year (1991) for which fleetwide reports were required, there were no major injuries reported with 9-D-5 training; there were a total of 17 minor injuries. The incidence of minor injuries was 28.3/100,000 evolutions. There were a total of 60,000 training evolutions conducted in 1991 fleetwide. Minor trauma was the most common

injury at 41.2% of all minor injuries--an incidence of 11.7. Table II summarizes these data for the 9-D-5 trainer.

There were only two HEELS incidents reported; both occurred in 1989. One was an "actuation failure" in a H-3 and the other, a "difficulty in locating" in a H-2.

There were 19 aircrew who reported a total of 21 problems with HEEDS use during helicopter Class A flight mishaps from 1987-1990. Of these, the most common were "Needed, not used" (4), "Donning/Removal" problems (5), and "Needed, not available" (5). Table III lists HEEDS problems coded by the Naval Safety Center.

4 DISCUSSION

Overall Survivability

Although the data show that there was no significant increase in the probability of survival for total Navy/Marine Corps aircrew in over water Class A survivable helicopter flight mishaps over the periods examined, there was a significant increase in the probability of survival from P1 to P2 to P3 for Navy aircrew in night over water mishaps. This suggests the programs studied may have contributed to the increase in survival probability of this group.

During P1, the number of night-time, passenger carrying missions was almost non-existent. The situation changed in 1982 with the decision to use night vision devices as a means of improving American night-fighting capabilities. Over the next few years, as the Marine Corps developed its night assault and insertion doctrine, night passenger carrying missions increased dramatically.

The improvement, though not statistically significant, seen in percent survival of night passengers from P2 to P3 may be attributed to several factors. First, when the Marine Corps initially began over water night-time personnel helicopter movements in 1982, troops ("passengers") routinely wore combat gear during over water flight. The bulk of this equipment rendered emergency egress through hatches and windows almost impossible. Many Marine Corps units now require this gear be stowed and donned just prior to disembarkation.

Second, the wearing of restraints while passengers were seated in flight was poorly enforced. If an over water inflight emergency did arise, it was quite likely that a substantial number of passengers would impact the water while unrestrained. It is almost impossible to keep a reference point or maintain orientation during unrestrained impact. Procedures now require the crew chief to brief passengers on strict compliance with all restraint regulations. Finally, since passengers are not formally trained in water survival, they are usually unfamiliar with the methods for safe egress from a sinking helicopter. The Marine Corps has recently instituted basic water survival training for ground forces prior to over water helicopter operations.

The 9-D-5 Device

Did the introduction of the 9-D-5 increase the probability of survival of over water survivable helicopter crashes? Considering only aircrew members, there was significant improvement in the night Navy aircrew survival from P1 to P2 to P3. This suggests the 9-D-5 training program has had a positive impact on the survival of this group. Furthermore, narrative reports prepared by aircrew mishap survivors generally indicate that water survival training was an important, positive

factor in the immediate post-crash water environment.

Water survival training involves much more than just the multi-place 9-D-5 trainer. The program includes swimming, using several strokes in full flight-gear for certain distances, treading water for a fixed period of time and "drown proofing" over a considerable time. It also includes trainee identification and utilization of all available survival gear, as well as training with other devices. These include the parachute drag, water entrance via the "slide for life", the parachute disentanglement device and the rescue procedures demonstrator.

Admittedly, not all of this experience is directly related to helicopter egress. However, the trainee receives considerable time in the water environment dealing with simulated survival activities. This experience serves to minimize the novelty of the water egress, instilling confidence which may help reduce initial panic.

Although the data indicate there was not an overall improvement in survival for total Navy/Marine Corps aircrew, it can not be concluded that the device has not made a positive contribution to overall survivability. The water survival program must, in the final analysis, be considered as a whole. Generally, it appears this type of training has saved lives.

Since its introduction, there has been one 9-D-5 associated fatality, a drowning victim at Pensacola. Overall, there have been only minor problems incurred during 9-D-5 device training. The data are somewhat limited, since central reporting was not required prior to fiscal year 1991 (FY 91). See Table II. Reports for that year show only minor injuries, the majority of which were blunt trauma sustained by contact with the device or with other trainees in the process of egress. Water aspiration was minimal in the few cases reported and did not lead to other, more serious complications. Minor muscle strains were the second most commonly reported injuries (Ref 3). Given the type of training and the level of physical intensity required, these kinds of injuries are not unexpected. The overall benefits of the training appear to outweigh the slight risk of injury.

The HEEDS Program

Did the introduction of HEEDS improve survival? The data suggest that HEEDS may have contributed to the significant improvement in survival probability seen from P1 to P2 to P3 in Navy aircrew on night over water crashes. In addition, based on aircrew narrative reports, it is clear that the HEEDS device has facilitated water escape. Individuals consistently reported a calming effect with the use of HEEDS, replacing the post-impact panic frequently experienced with the initial inrush of water, cold shock, and disorientation. With HEEDS use, the aircrew has additional time to help passengers safely egress. The Marine Corps is seriously considering training ground troops in HEEDS use and supplying the device for over-water missions.

Most of the problems encountered with HEEDS can be attributed to the device's procurement history. Acquired as an add-on to the already existing survival vest, the long, bulky oxygen canister replaced an unrelated piece of equipment in the vest left, front pocket. To hold it in place, it was attached by a lanyard. There have been reported problems with both removal and the initial donning. On occasion, the device was lost because the lanyard was not secured, or was absent altogether. There are several reports of minor injuries from contact with the device. There will soon be available a more compact version, ultimately replacing the present system. However, availability problems due to aircrew failure to

properly pre-flight personal gear or paraloft error, such as failure to attach the restraining lanyard, will continue. In an attempt to minimize these types of human errors, the U. S. Coast Guard recently redesigned the device. In their version, the cylinder is an integral part of the survival vest with long, flexible tubing and a mouth-piece attached. Only the mouth-piece need be located, retrieved and brought to the mouth for use.

Parenthetically, the institution of HEELS may also have contributed to the improvement seen in passenger survival. However, there are insufficient data on the actual use of HEELS in class A flight mishaps over water to make any definite statements.

5 CONCLUSIONS

Although there has been no significant increase in combined Navy/Marine Corps over water survivable Class A helicopter flight mishap survivability during the period examined, data show that there was a statistically significant increase in probability of survival for P1 to P2 to P3 for Navy aircrew in night survivable crashes over water. This suggests that the 9-D-5 device and HEEDS both may have had positive effects on the probability of survival of this subgroup. The environment in which these mishaps occur continues to evolve. As more and more operations are conducted at night, the risk of fatality in an otherwise survivable impact becomes greater. The institution of 9-D-5 training as part of the Water Survival Training Program (WSTP) may have contributed to the relatively stable combined Navy/Marine Corps aircrew survival during the period examined. The 9-D-5 training closely simulates the post-water impact environment and aircrew members learn the skills required for survival. The benefits of such training far outweigh the risks. The WSTP should become part of the required training for Marine Corps personnel involved in regular over water evolutions.

Because aircrew with HEEDS have more time to help passengers escape, the HEEDS may have been partially responsible for the apparent increase in percent survival for Navy/Marine Corps night passenger survival seen from P2 to P3. Most of the problems reported with using this device seem easily correctable and training in HEEDS use should be extended to special categories of passengers that are at very high risk, e. g. Marine Corps ground troops transported by helicopters during amphibious operations.

There are insufficient HEELS data, but interviews with survivors continue to emphasize the visual difficulties encountered during water egress, especially at night. It seems most likely emergency lighting will help.

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