TWENTYFIFTH EUROPEAN ROTORCRAFT FORUM

Paper No. L4

ANALYSIS OF ARMY HELICOPTER PILOT ERROR MISHAP DATA AND THE IMPLICATIONS FOR HANDLING QUALITIES

by
David L. Key
Army/NASA Rotorcraft Division
Aeroflightdynamics Directorate, AVRDEC.
US Army AMCOM

September 14-16, 1999

Rome, Italy

ASSOCIAZIONE INDUSTRIE PER L'AEROSPAZIO, I SISTEMI E LA DIFENSA ASSOCIAZIONE ITALIANA DI AERONAUTICA ED ASTRONAUTICA

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1 SUMMARY

This paper describes a survey of US Army pilot error mishap data to determine if trends show any implications for handling qualities. The work was motivated by two considerations: First, the increasing accident rates, especially at night and in degraded visual environments. Second, the ongoing opportunity to upgrade two of the current fleet, the cargo CH-47 Chinook, and the utility UH-60 Black Hawk. Data used was US Army Safety Center summaries of pilot error mishaps for the period 1986-1996, for the AH-64A, CH-47D, H-60 (includes the UH-60A, UH-60L, and MH-60L) and the OH-58D. Summaries were reviewed and the mishap situations assigned to several categories related to task difficulty, situation awareness and visual environment. The results suggest that poor handling qualities can exist while performing hover and low speed tasks, especially in degraded visual environments, and should be considered a potentially hazardous condition. Piloted simulation studies have shown that handling qualities improvements are possible with stability and control augmentation schemes which give an attitude command response type. Recent investigations suggest that the benefits of attitude command can be obtained even with the limited authority stability and control augmentation systems existing in the current fleet. Except for the AH-64A Apache, mishaps in low speed maneuvering flight were much more prevalent than accidents that start from hover. This suggests that hover position hold alone would not significantly reduce the accident rate.

2 MOTIVATION

Several factors have recently motivated a review of US Army accident statistics to determine if they can be related to potential handling qualities improvements.

Current US Army doctrine places a high priority on operations at night and in bad weather. Night vision devices such as Night Vision Goggles (NVG) allow operations to be carried out in otherwise impossibly low light levels. However, US Army Safety Center statistics (ref. 1) show a significant increase in accident rates over the period 1996-1998, especially when using NVG. Specifically, for the UH-60, the rate of A-C class mishaps (more than $10,000 damage) on NVGs increased by a factor of 3, from less than 9 per 100,000 flight hours in 1996 to 27 per 100,000 flight hours in 1998. The Day accident rate decreased from about 9 to 7, and the night (unaided) remained at about 15 per 100,000 flight hours. The US Army Safety Center conjecture is that the reduced flight experience of the pilot in command (from 1327 hours in 1992 to 536 in 1997) may be a significant factor in the increased accident rate on NVG.

Handling qualities research over the last decade has shown that control laws optimized for day operations result in poor handling qualities in a degraded visual environment such as at night. Stability and control augmentation systems that provide increased stabilization can compensate for the lack of visual cues and maintain good handling qualities into significantly degraded conditions.

The US Army is starting a program to upgrade two of the current helicopter fleet, the large cargo CH-47, and the medium utility UH-60. This will not only improve reliability and maintainability, but also will provide increased capacity and allow more elaborate control laws to be accommodated.

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* Paper presented at the 25th European Rotorcraft Forum September 1999.

Hover Position Hold (PH) is a familiar concept so it gets wide acceptance. A much less familiar concept is a response type called Attitude Command Attitude Hold (ACAH). A modification of control laws to achieve ACAH response type can significantly improve the handling qualities in a Degraded Visual Environment (DVE) such as when using night vision goggles. Unlike PH, ACAH improvements cover low speed maneuvering to about 50 kt, as well as in and around hover. Although it is not possible to achieve pure ACAH with the existing hydro-mechanical control systems, some new developments in handling qualities research suggest that it is possible to achieve the benefits of ACAH with only very modest hardware changes.

These considerations motivated a look at accident situations to see if they may reflect deficient handling qualities. Dr Sam Crews of the Aviation and Missile Command, (AMCOM) Directorate of Engineering obtained Army Aviation Safety Center Pilot Error Mishap Summaries for 1986-1996 for the Aeroflightdynamics Directorate (AFDD) to review.

3 BACKGROUND

3.1 Handling Qualities

First it is important to be clear what is meant by Handling Qualities (HQ). The definition most frequently used is that provided by two pioneers, George Cooper and Robert Harper (ref. 2), “handling qualities are those characteristics which govern the ease and precision with which a pilot is able to perform those flight tasks in support of an aircraft role”. Figure 1 illustrates the ingredients that make up those HQ characteristics. When a pilot performs a given task with a given set of flying qualities, the handling qualities will depend on how aggressively and precisely the task has to be performed, and also on the visual and atmospheric environment.

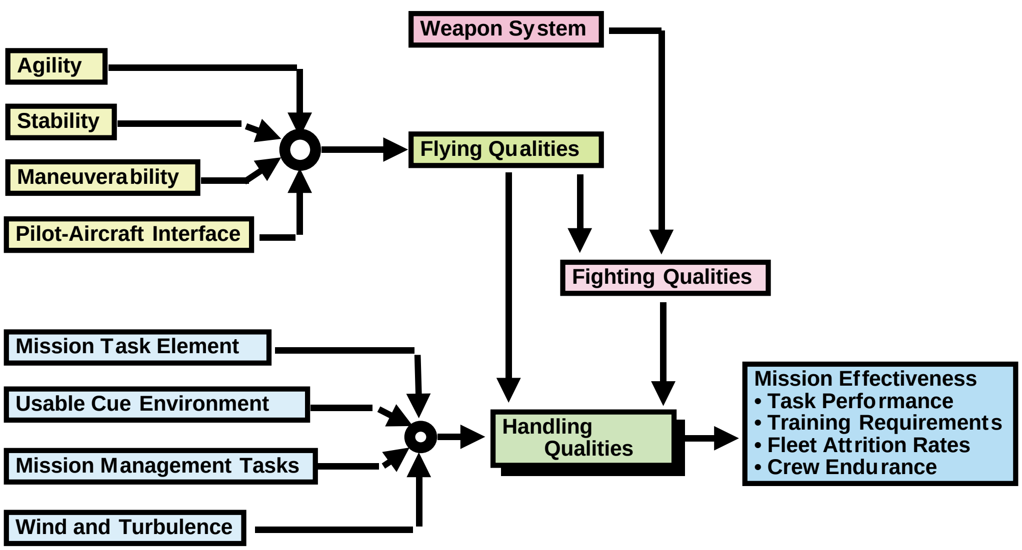

Figure 1: Illustration of ingredients influencing handling qualities.

There are so many parameters which influence HQ that the only sure way to assess them is by subjective pilot opinion. The method most widely used is for experienced test pilots to perform well defined tasks and use the Cooper-Harper Handling Qualities Rating (HQR) scale (fig 2). Important break points on this scale are HQR 3 to 4, where the HQ change from Level 1 (desired levels of mission performance are attainable with minimal pilot compensation (skill and attention)) to Level 2 (mission performance still possible, but deficiencies warrant improvement and only adequate mission performance may be attainable with extensive pilot compensation), and HQR 6 to 7, where the HQ change from Level 2 to Level 3 (major deficiencies, and adequate mission performance not attainable even with maximum tolerable pilot compensation).

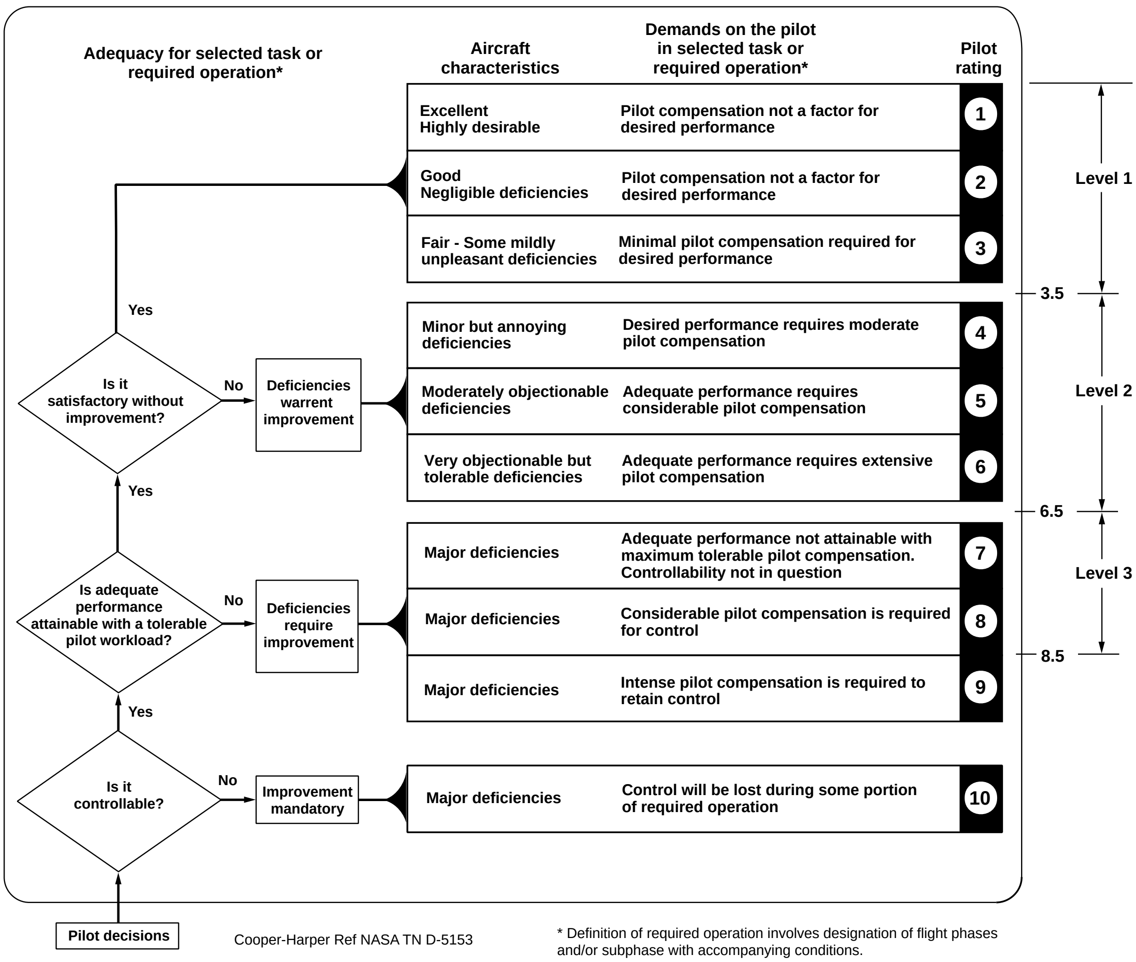

Figure 2 Handling qualities rating scale

3.2 Situation Awareness

There are many definitions of Situation Awareness in the literature, but for the purposes of this discussion, the definition will follow Hoh, (ref. 3), since it focuses attention on the aspects of most concern without reference to the wider tactical situation. That is, Situation Awareness (SA) is the comprehension of position, velocity and attitude with respect to the ground, and all objects in the vicinity of the rotorcraft.

Attention must be drawn to the fact that HQ is an assessment of task performance precision and aggressiveness, and the pilot compensation required to achieve that level of performance. Good HQ means that the pilot is able to perform the mission tasks to the desired level of precision and aggressiveness with minimal compensation. This in turn means that the pilot is able to not only do the flight tasks to the desired standards, but the attention demand required to achieve those standards leaves some Excess Workload Capacity (EWC). This EWC is then available for developing an appropriate SA. Poor HQ implies just the opposite; adequate performance standards cannot be achieved, or the pilot compensation is excessive, or both. In this situation, attention demand may be close to 100% so the EWC is near zero, and SA could be significantly reduced. If the HQ are bad enough, the pilot may not even be able to retain control. A theoretical development of the relation between HQ, SA and EWC was presented in a recent paper by Hoh (ref. 3).

3.3 Spatial Disorientation

Before continuing with the assessment of handling qualities effects on safety it is instructive to look at another paradigm for classifying accidents, that is Spatial Disorientation (SD). Authors such as Durnford (ref. 4) and Braithwaite (ref. 5) adopt the following definition:

> "SD is the situation occurring when the aviator fails to sense correctly the position, motion, or attitude of his aircraft or of himself within the fixed coordinate system provided by the surface of the earth and the gravitational vertical." They add clarification that "errors in perception by the pilot of his position, motion or attitude with respect to his aircraft, or of his own aircraft relative to another aircraft may also be embraced within the broader definition of SD in flight. This excludes getting lost, but includes contact with an obstacle known to be present but misjudged to be sufficiently separated from the aircraft. Contact with an obstacle whose presence was simply unknown was not considered to be SD."

They then use SD as a paradigm for understanding and classifying mishaps involving helicopter pilot errors. This focus on perception has resulted in the possible benefits of improved HQ being ignored. Instead, it has focused efforts for alleviating the accidents on providing more cues to the pilot, better scanning, and improved crew coordination. For Example, ref. 5 requested the flight surgeons that reviewed the accidents to check a list of potential solutions and got the responses shown in fig. 3. Clearly there are benefits to be gained from making improvements in crew coordination, scanning, etc. However as will be shown below, improving the HQ can have a big effect on the pilot's ability to perform tasks precisely with minimal skill and attention. The improved precision should reduce inadvertent contact with obstacles, and the reduced skill and attention demanded should reduce training and proficiency requirements.

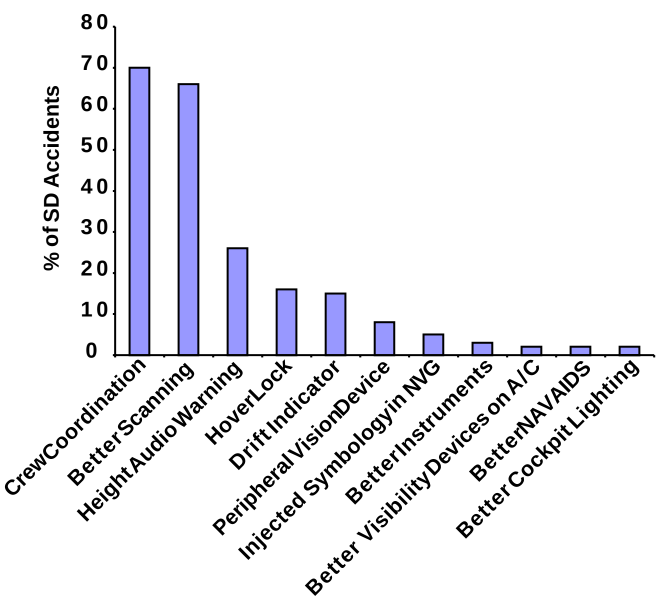

Figure 3: Potential solutions for pilot error mishaps suggested by flight surgeons.

3.4 Handling Qualities in a Degraded Visual Environment

Using the definitions implied by fig. 1, it can be seen that it is possible for an aircraft with certain flying qualities performing a task in the day with a Good Visual Environment (GVE) to have excellent handling qualities, while if the same task is attempted at night in a DVE it could have very poor handling qualities. This is in fact often the case.

In hover and low-speed flight helicopters are inherently unstable. That means small changes in attitude will grow unless the pilot continuously uses the controls to maintain that attitude. Unless he lets the divergence build-up, the required control inputs are small, but frequent. HQ engineers refer to this attitude maintenance as the "inner loop" control. The pilot modulates attitude to generate linear acceleration, in time this integrates to give velocity, and eventually a new position. This part of the control task is referred to as the "outer loop" control. During hover and low speed maneuvering in a DVE, it is the inner loop task that is most difficult, and which deteriorates most rapidly as the visual cues degrade.

The helicopter's response to a step input in pitch or roll control is to eventually establish a constant pitch or roll rate. The longer it takes to reach a steady rate, the less damping the response has, and the more difficult it is to control. Hence, though they vary in sophistication from the OH-58 to the UH-60, AH-64, and CH-47, all of the Army's helicopters have augmentation systems that increase the rate damping. The resulting response is called Rate Command (RC). Since the rate damping inputs are small and have relatively high frequency, they can be achieved with actuators having only 10% of the authority that the pilot has available. This will be called a Limited Authority Stability and Control Augmentation System.

With a Rate Command system, to move from a hover to a forward speed the pilot has to go through two cycles of control deflection and centering, while continuously closing the inner loop to stop the helicopter from diverging:

- push the stick forward to develop a nose-down pitch rate,
- remove the control input when he predicts that he will stop at the attitude that he predicts will give him the appropriate forward acceleration,
- pull the stick back to develop a nose-up pitch rate when he predicts that removing the acceleration will result in the desired velocity
- remove the control input when he predicts that the attitude appropriate for the new speed will be reached.

In GVE, with good flying qualities, pilots soon learn to use the cues needed to perform such tasks precisely and aggressively. In DVE the visual cues are less apparent, predictability is worse, so the tasks are much more difficult.

As the visual cues deteriorate, in the limit, as in a brownout, the pilot loses all visual cues, so he can neither see nearby objects, nor get the cues necessary to close the inner loop to provide stabilization. However, there is a range of DVE within which the pilot can still see the nearby prominent objects for outer loop guidance, but the cues necessary to perform the inner loop stabilization task are obscured to some degree. ADS-33D (ref. 6) defines three levels of visual cueing. The first is good visual environment. The other two define environments where the flight control laws should be changed to compensate for degraded visual cues. To calibrate these environments it uses a Usable Cue Environment (UCE) scale (fig. 4).

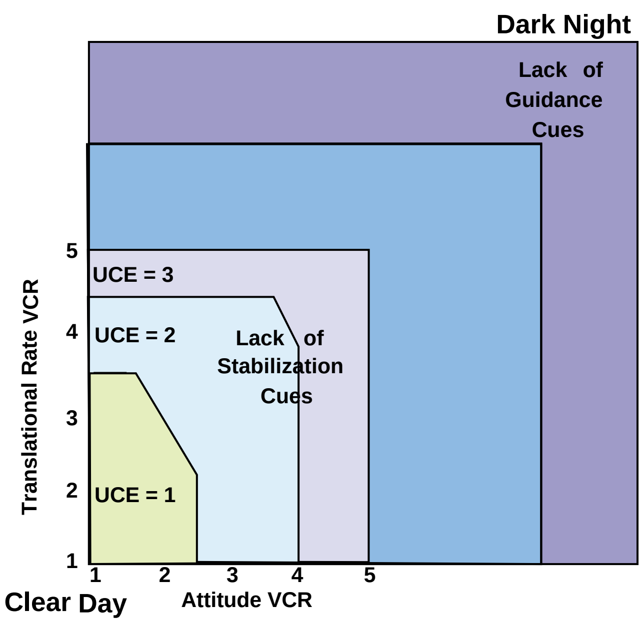

Figure 4: ADS-33D Usable Cue Environment Scale.

Many factors affect the UCE, depending on the characteristics of the vision aid and the features that are available to look at. The technique for establishing the UCE is defined in ADS-33D. In very simple terms the three levels correspond to:

- UCE=1. This is a GVE typical of clear daylight flight over well defined terrain.
- UCE=2. This is a DVE typical of a moonless night while using ANVS-5 NVG. For a rough benchmark this would imply a visual acuity in the range of 0.7 cycles/milliradian (approximately 20/50 on the Snellen scale) down to 0.4 c/mr (20/80).
- UCE=3. This is into the range of an overcast moonless night with NVG, and probably extends down to 0.2 c/mr (20/200).

The minimum control laws that are required by ADS-33D to maintain good HQ (HQR 3 to 4) in the three UCE are basically:

- In UCE=1: Rate Command (RC).
- In UCE=2: Pitch and roll Attitude Command Attitude Hold (ACAH). Yaw Rate Command with Heading Hold. Vertical Rate Command with Height Hold.
- In UCE=3: Horizontal Translational Rate Command. Vertical Rate Command with Height Hold.

The actual AFCS characteristics provided in the current Army helicopter fleet are basically RC in pitch and roll, though some have Yaw Rate Command with Heading Hold and Vertical Rate Command with Height Hold. These response types can be fully satisfactory for UCE=1, but would be expected to be marginal in UCE=2 and even worse in UCE=3. Research by AFDD (refs. 8, 9, and 10) has demonstrated the feasibility of implementing the desired

ACAH response types even with the existing limited authority SCAS servos. In the ref. 8 simulator trials several control law configurations were implemented on a UH-60A math model to achieve ACAH in pitch and roll. These were evaluated while performing three tasks from ADS-33D, ref. 6 (hover, sidestep and acceleration-deceleration) in a simulated DVE with ANVS-5 night vision goggles. The results show that the ACAH effectiveness can be extended to high levels of maneuvering aggressiveness, with pitch and roll angles of about 15 deg. Also, as the SCAS actuators approach their limits, the attitude command characteristic can be phased out, and back in, without demanding significant pilot compensation.

With the existing RC systems for pitch and roll, the HQ would be predicted to deteriorate to the HQR=5-6 region in UCE=2. This means that the pilot will not be able to achieve desired standards of performance, and even adequate performance will require considerable compensation (skill and attention). Workload will be high and detract from situation awareness, and flight control precision will be marginal.

In UCE=3, the HQ would be predicted to deteriorate to the HQR=6-7 region. This means that even adequate performance demands intense compensation. Workload will be very high, SA will be poor, and flight control precision will be poor. If the pilot should enter worse than UCE=3 (e.g. a brownout,) he will not be able to see where he is going (lack of guidance cues) and may drift, so SA will appear completely lacking. In addition the pilot will have great difficulty even maintaining control.

Since all of the current fleet have flight control systems that basically provide RC in pitch and roll, it is suggested that the following table indicates the probability that HQ and SA would contribute to a mishap.

Task difficulty	Visual Environment		
	UCE=1	UCE=2	UCE=3 or worse
Easy	Low	Medium	High
Moderate	Low	High	High
Difficult	Medium	High	High

Table 1: Likelihood that HQ and SA Contributed to Accident (for RC systems).

Where UCE is defined as above, and the task difficulty is defined as follows:

Easy: Low precision and aggressiveness required.

Moderate: Some requirement to be precise or aggressive.

Difficult: Must be precise and/or aggressive.

4 PILOT ERROR MISHAP ANALYSIS

Considering the motivations and definitions described above, accident summaries were analyzed to see the extent to which the class A-C mishaps summarized in ref. 7 could be explained by poor handling qualities.

The definitions of A, B, and C accident classes are essentially:

Class A: More than $1,000,000 damage and/or a fatality.

Class B: Between $200,000 and $1,000,000 damage and/or a permanent disability.

Class C: Between $10,000 and $200,000 damage and/or a disability lasting beyond the day of the accident.

The pilot mishap summaries were reviewed and the following group categories were assigned. It should be noted that several of the categories apply to most mishaps.

- <u>HQ and SA:</u> is an interpretation of the summary that the mishap involved a problem in precision of control, high pilot workload, and/or poor spatial situation awareness. The considerations that lead to categorizing the mishap as HQ and SA are summarized by table 1 ratings of medium and high.

- Hover: means that the mishap started while trying to maintain a steady hover.
- Low Speed Maneuvering: means that the event happened while in a low speed maneuver, which includes attempting to establish a hover at a particular spot.
- NVG: means the summary explicitly stated, or implied, that the flight was using night vision aids.
- Brownout: means these mishaps involved a brownout or whiteout.
- Air Taxi, Ground Taxi, etc: means these mishaps involved ground taxi, air taxi etc.
- Tree Strikes: means that the summary stated that main or tail rotor hit a tree.
- Wire Strike: means that the helicopter hit a wire.
- Mechanical failure: means that these events had some sort of failure, ranging from an engine failure to an access cover falling off.
- Caution Warning: means that the summary implicated distraction from a real or false warning for initiating the event.
- Sling Load: means that these events involved sling load operations.

The following are a few mishap summaries that illustrate the symptoms of poor control precision and very high workload. Typically the pilot can see the obstacle or knows his position, he just has trouble maintaining precise control.

Loss of control and SA following entry to a brownout.

UPON RETURN FROM A COMBAT MISSION IN IRAQ, THE ACCIDENT AIRCRAFT WAS MAKING A NIGHT VISION SYSTEMS APPROACH TO THE REAR ASSEMBLY AREA. ON SHORT FINAL, THE CREW EXTENDED THEIR APPROACH DUE TO A FOXHOLE TO THEIR FRONT, THEN BECAME DISTRACTED WHILE LOOKING FOR ARMAMENT GROUNDING STAKES STICKING OUT OF THE GROUND. THE AIRCRAFT BECAME ENVELOPED IN DUST, THEN BEGAN DRIFTING LEFT WHERE IT IMPACTED WITH ANOTHER AIRCRAFT ON THE GROUND. BOTH AIRCRAFT SUSTAINED MAJOR DAMAGE, AND THERE WERE NO INJURIES TO ANY OF THE CREWMEMBERS.

Poor control and SA while maneuvering in a confined area (NVG).

AIRCREW WAS PERFORMING NVG CONTINUATION TRAINING. CREW HAD JUST LANDED ON A PINNACLE AND IP DECIDED TO REPOSITION THE AIRCRAFT. THE IP BROUGHT THE AIRCRAFT TO A HOVER AND BEGAN MOVING THE HELICOPTER TO THE LEFT. THE CREW HEARD A NOISE AND AIRCRAFT BEGAN VIBRATING. THE IP LANDED THE AIRCRAFT AND THE VIBRATIONS BECAME SEVERE. THE AIRCRAFT HAD DRIFTED BACKWARD INTO A SMALL TREE, DESTROYING THE TAIL ROTOR BLADES, DAMAGING THE TAIL BOOM AND HORIZONTAL FIN STABILIZER.

Poor control while attempting to hook a sling load, (NVG).

This is an interesting illustration of just how bad it must be under a CH-47D when attempting to hook loads. The time taken for the attempts is extreme and shows the need for precise positioning as quickly as possible.

AIRCREW OF ACFT WERE ATTEMPTING TO HOOK UP A TANDEM EXTERNAL LOAD AT NIGHT UNDER NIGHT VISION GOGGLES (PVS5'S). DIFFICULTY WAS ENCOUNTERED DURING THE HOOK UP ATTEMPT. AFTER 15-20 MINUTES THE FORWARD HOOK UP MAN INCORRECTLY HOOKED THE CLEVIS TO THE CENTER HOOK. THE CLEVIS WAS RELEASED BY THE FLIGHT CREW. THE AIRCRAFT MOVED ASIDE, LANDED, AND THE FLIGHT ENGINEER BRIEFED THE HOOK UP CREW ON THE PROPER HOOK UP PROCEDURES, STRESSING THAT THE HOOK UP MEN MUST MAKE A MORE AGGRESSIVE ATTEMPT TO FULLY STAND UP AND HOOK UP THE VEHICLE TO THE AIRCRAFT'S FORWARD AND AFT HOOKS. AFTER 5 MINUTES, DURING THE SECOND ATTEMPT, THE FORWARD HOOK WAS SUCCESSFULLY HOOKED. WHILE ATTEMPTING TO HOOK THE AFT HOOK, (AFTER ANOTHER 10 MINUTES HAD PASSED) THE PILOT FELT A BUMP (IT IS SUSPECTED THE SLINGS CAUGHT ON THE GUN) AND THINKING HE HAD CONTACTED THE GUN, INCREASED HIS ALTITUDE, THEREBY LIFTING THE GUN OFF THE GROUND SLOWLY. THE GROUND CREW RAN CLEAR WITH THE EXCEPTION OF ONE SOLDIER WHO HAD BEEN STANDING BETWEEN THE GUN TRAILS AND COULDN'T DECIDE WHICH WAY TO RUN. THE FLIGHT CREW WAITED UNTIL THE LAST SOLDIER CLEARED AND AT THIS POINT, THE GUN WAS NOW COMPLETELY OFF THE GROUND HAD BEGUN TO OSCILLATE. THE FLIGHT ENGINEER FEELING THE GUN MIGHT CONTACT THE AIRCRAFT JETTISONED THE GUN. THE TRAILS OF THE GUN HIT FIRST FOLLOWED BY THE WHEELS, AND CAME TO REST. THERE

WERE NO INJURIES NOR DAMAGE TO THE AIRCRAFT. THE GUN SUFFERED DAMAGE TO THE CARRIAGE AND THE WHEEL ASSEMBLY.

Disorientation and poor control over water (NVG).
Note that the pilot was calling out altitudes for the copilot on the controls, so additional instruments and warning systems may not have helped.

THE ACFT PILOT ON A NVG MISSION, EXPERIENCED VERTIGO WHILE MAKING A LOW-LEVEL PASS AT AN OBJECT IN OPEN WATER UNDER LOW ILLUMINATION CONDITIONS. AFTER CLIMBING THE AIRCRAFT ON INSTRUMENTS TO AN ALTITUDE OF 250 - 300 FEET, AIRCRAFT CONTROL WAS TRANSFERRED TO THE COPILOT IN THE RIGHT SEAT. THE COPILOT LEVELED THE AIRCRAFT AND INITIATED A SHALLOW DESCENT TO RETURN TO THE VICINITY OF THE OBJECT UNDER OBSERVATION. THE PILOT OBSERVED THE AIRCRAFT IN A RAPID DESCENT AND CALLED OUT THE ALTITUDES STARTING AT 50 FEET ON THE RADAR ALTIMETER. BOTH PILOTS PULLED MAXIMUM COLLECTIVE PITCH AS THE AIRCRAFT NEARED THE SURFACE OF THE WATER. THE AIRCRAFT IMPACTED LEVEL WITH LITTLE FORWARD MOMENTUM AND ROLLED RIGHT 120 DEGREES COMING TO REST IN 3 TO 5 FEET OF WATER.

Loss of control after distraction in DVE (NVG).
This summary illustrates that in a very high workload situation too many warnings can in fact be detrimental.

DURING NIGHT VISION GOGGLE (NVG) PROFICIENCY TRAINING, WHILE ON THE CROSSWIND LEG OF THE AIRFIELD TRAFFIC PATTERN AT LESS THAN 200 FEET AGL, THE MASTER CAUTION LIGHT AND #2 PRIMARY SERVO CAUTION LIGHT ILLUMINATED. THE PILOT AND COPILOT DIVERTED THEIR ATTENTION INSIDE THE COCKPIT WHILE ANALYZING THE SITUATION. OUTSIDE VISUAL REFERENCE WAS NOT CONTINUOUSLY MAINTAINED AND THE AIRCRAFT BEGAN TO DESCEND. WHEN THE PILOT LOOKED OUT TO REGAIN VISUAL REFERENCE, NO VISUAL REFERENCES COULD BE FOUND DUE TO LOW ALTITUDE AND SNOW-COVERED TERRAIN. AS THE PILOT ATTEMPTED TO TRANSITION TO INSTRUMENT FLIGHT, THE AIRCRAFT IMPACTED THE GROUND APPROXIMATELY ONE MILE SOUTH OF THE AIRFIELD. THE AIRCRAFT SLID AND ROLLED, COMING TO REST ON ITS SIDE……

4.1 Review of Mishap Summaries

Figure 5 shows the data for the Black Hawk family (UH-60A, UH-60L and MH60L combined), the Chinook (CH-47D), Apache (AH-64A), and the Kiowa Warrior (OH-58D). Some interesting conclusions can be drawn from the numbers:

Of the 276 total mishaps, 123 were grouped as HQ and SA. For the H-60 and CH-47D, about 30% of the total mishaps involve HQ and SA. The proportion is about 50% for the class A mishaps. For the AH-64A and OH-58D the numbers are even higher at 50% of total and about 80% for the class A mishaps. It is concluded that many of these HQ and SA mishaps could have been avoided with HQ more suitable to the DVE.

Many more mishaps occurred from low speed maneuvering flight than from hover. The factor of low speed maneuvering to hover incidents was 7 for the H-60, 5 for OH-58D, and 2 for the CH-47D. Only on the AH-64A were the two incidences about equal. A primary mission for the Apache involves reconnaissance and weapon firing from hover, so protracted hovering, for 10 minutes or more, is a frequently performed task. It is therefore somewhat surprising that the proportion of mishaps from low speed maneuvering was so high. The OH-58D, which performs similar reconnaissance task, had an extremely high proportion of mishaps starting from low speed maneuvering. These numbers imply that ACAH would generally be of much more benefit than PH, and even on the AH-64A, to improve safety it would be desirable to incorporate ACAH as well as PH.

The H-60 and CH-47D had remarkably few mishaps during sling load operations, and even then it was usually the load that was damaged not the helicopter, resulting in a class C mishap. However, adverse circumstances such as blowing dust can result in very long times (10 to 15 minutes) to achieve drop off or hook-up. It is easy to understand why a hook-up crewman could get things wrong when he is standing in the dark, in a tornado of downwash with a 46,000 lb helicopter drifting around inches above his head. Clearly, it is very important to

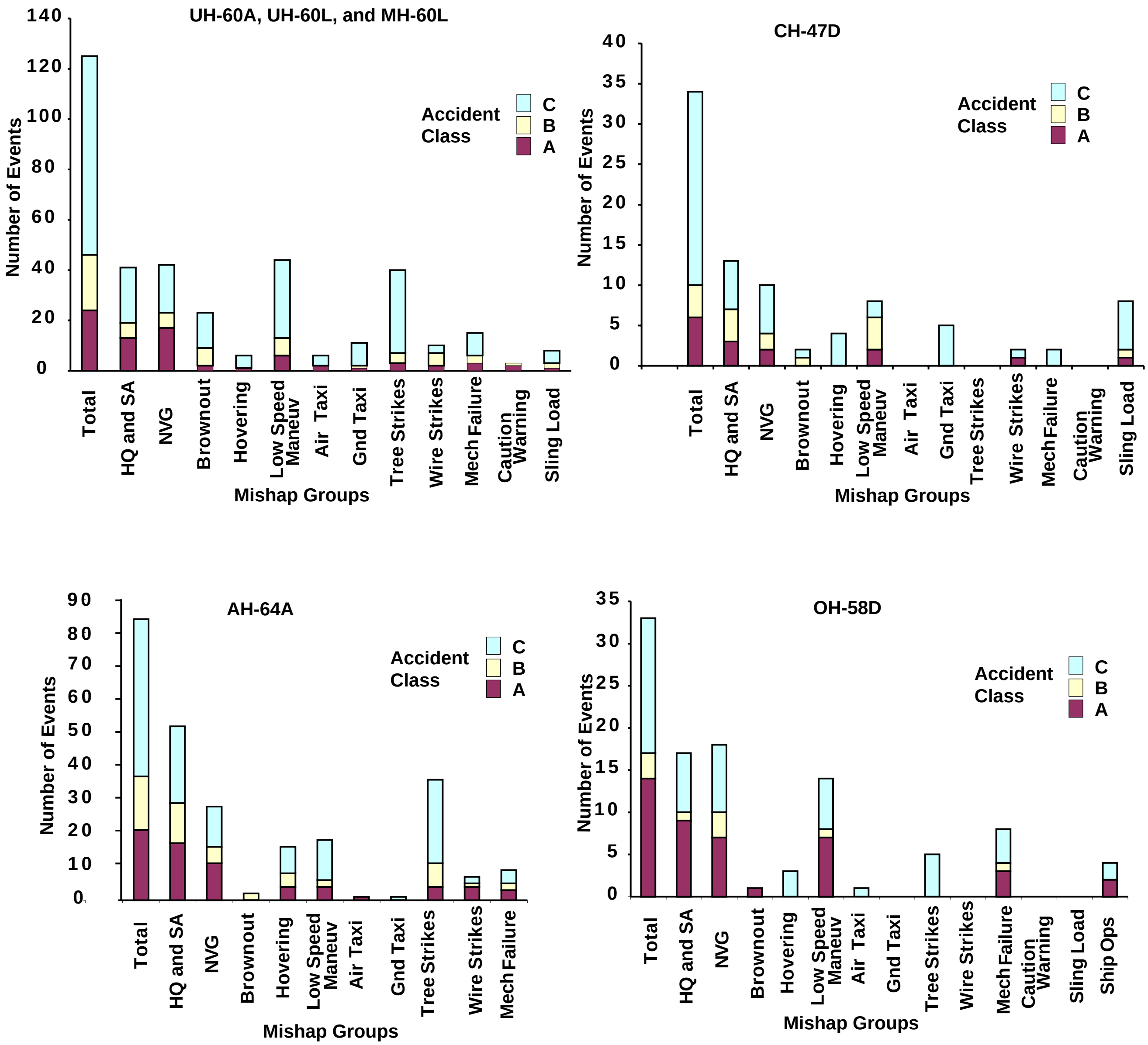

Figure 5: Pilot error mishaps 1986-1996. BlackHawk (MH-60L, UH-60A, UH-60L), Chinook (CH-47D), Apache (AH-64A), and Kiowa Warrior (OH-58D).

optimize HQ so that the pilot is able to achieve the appropriate hook-up position quickly and maintain it precisely for at least 20 seconds or so.

5 CONCLUSIONS

This survey of pilot mishap summaries clearly indicates that a large proportion of accidents involve poor control precision and/or poor situation awareness, and that they occur in hovering and low speed flight in degraded visual environments.

Comparison of existing stability and control characteristics with those recommended in US Army specification, ADS-33, show that Level 2 or worse handling qualities, would generally be expected in degraded visual environments typically encountered in night operations.

Improved handling qualities and reduced accident rates should be possible with flight control augmentation systems modified to give Attitude Command response type. Such a response type should be achievable on current fleet helicopters with minimal hardware changes.

Mishaps from low speed maneuvering are significantly more prevalent than mishaps that start from hover, so hover position hold alone would not be expected to significantly reduce the accident rate.

Accident rates seem to be increasing as pilot experience falls. This also points to inadequate handling qualities. Since flight time/proficiency is likely to continue to decrease, it places even more emphasis on achieving good handling qualities so as to demand less skill from the pilot.

As defined in this study, marginal or deficient HQ have a strong correlation with pilot error mishaps. It is therefore recommended that when analyzing and classifying accidents the safety authorities define marginal HQ as a potentially hazardous condition.

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