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CASE REPORT

To Err is Human
Case Reports of Two Military Aircraft Accidents
Possible mechanisms of human failure

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خطأ الانسان - تقرير حالتين من حوادث الطيران الحربي
احتمال آليات فشل الإنسان

موهان ديكشيت

الخلاصة: من المفترض أن أخطاء الطيار أو عجزه وضعف أدائه أثناء الطيران ربما يكون العامل المسبب لحوادث الطيران في (%70-80) من حوادث الطيران. ندرج هنا حادثتي طيران مميتتين ربما كانتا بسبب أحد العاملين المذكورين. الحالة الأولى تصف قرار خاطىء لطيار حربي لاستعمال كرسيه في حالة القذف من الطائرة سببت الوفاة. تم افتراض آلية الحادث القاتل وذلك من خلال إصابات جسم الطيار والتدقيق في ملابسه وكرسي القذف. أما الحالة الثانية فهي تصف سلسلة من الأحداث التي انتهت بعجز الطيار أثناء تنفيذ مناورة عادية، مما أدى إلى حادث مميت. قمنا بمناقشة العوامل البيئية التي ربما سببت فشلا في الآليات الفسيولوجية للطيار مما أدى إلى الحادث.

مفتاح الكلمات: حوادث الطيران، تَوَهانٌ حيِّزيّ، مقعد القذف، اصابة، ملابس الطيران، فقدان الوعي بسبب الجاذبية، شل القدرة، في الطيران، أخطاء الطيار.

Abstract: It has been postulated that pilot error or in-flight incapacitation may be the main contributory factors to 70–80% of aircraft accidents. Two fatal aircraft accidents are presented in which either of the above possibilities may have played a role. The first case report describes an erroneous decision by a fighter pilot to use a seat position adjustment of the ejection seat leading to fatal injuries when he had to eject from his aircraft. Injuries to the body of the pilot, and observations on the state of his flying clothing and the ejection seat were used to postulate the mechanism of fatal injury and establish the cause of the accident. The second case report describes the sequence of events which culminated in the incapacitation of a fighter pilot while executing a routine manouevre. This resulted in a fatal air crash. Possible contributions of environmental factors which may have resulted in failure of his physiological mechanisms are discussed.

Keywords: Aviation accident; Spatial disorientation; Ejection seat; Injury; Flying clothing; Gravity-induced loss of consciousness; Incapacitation, in-flight; Pilot error.

Ever since the beginning of aviation in 1904, rapid strides have been made in the development of aircraft performance. This has imposed severe stress on the human operator whose physiology has remained unchanged. Development of life support systems such as sophisticated oxygen systems, escape systems, flying clothing and cockpit layout and instrumentation have helped man to cope with the increasing stress. And yet there are occasions when, under a given set of circumstances, various factors interact to produce an untoward incident called an accident. In military aviation, an aircraft accident is defined as: "An occurrence, not directly caused by enemy action, involving one or more aircraft, which happens during the operation of any one of these aircraft, and which results in injury to one or persons, or damage to aircraft or property."[1] A variety of reasons such as technical failure and inclement weather conditions may have a role to play, but it is has been generally accepted that in as many as 70–80% of aircraft accidents, various levels of human operator error are likely to be a contributory cause.[2] An analysis of fatal aircraft accidents in the Indian Air Force indicated that 68% were caused by "pilot error".[3]

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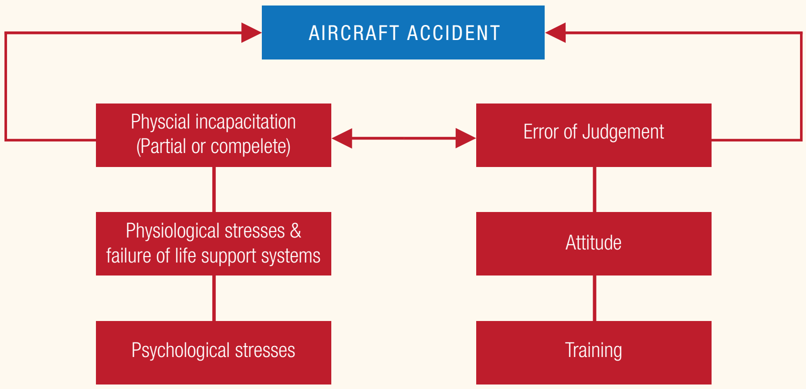

Figure 1: Possible algorithm for occurrence of an aircraft accident which may be caused by pilot error/incapacitation.

A flow chart has been constructed to outline various reasons which may induce pilot error [Figure 1]. The final outcome may be precipitated because of pilot incapacitation or an error of judgment and possibly caused by a combination of circumstances. This case report attempts to highlight human frailty which may have led to fatal outcomes in two accidents involving Indian Air Force aircraft and aircrew. These incidents have been chosen as they had occurred in the early 1970s, and hence do not compromise military intelligence. Where ever possible, an attempt has been made to use the findings at autopsy to explain the possible reasons for a fatal outcome to the pilot involved.

Case Report One

The pilot of a Sukhoi 7 B supersonic fighter bomber (Flying Officer V) was seen to eject from the aircraft at low level. The army rescue patrol found the pilot dead. No obvious injury was noticed. The flying clothing of the pilot, including the oxygen mask and the protective helmet were apparently intact, as was the parachute to which he was still attached. The ejection seat was recovered from some distance from the site where he was found. The body was evacuated to a forward dressing station where it was examined by an Army medical officer (MO). He noted that there was a large contusion on the forehead, and an extensive pulpy swelling which he described as a possible haematoma on the back of the head. He disposed of the body as per operational orders, but had the ejection seat and the flying clothing sent to the pilot's airbase. There the items were examined by the flight surgeon. He noticed that the protective helmet had a dent in the front area which would have been covering the forehead. The area of impact had some debris which could be matched with the front, lower margin of the aircraft cockpit canopy. The back of the helmet was also dented. This dent was impacted with the leather debris from the head rest of the ejection seat. The findings indicated that the forehead of the pilot was struck by the rear end of the canopy, which in turn had smashed the back of the head in to the head rest of the ejection seat. When this possibility was correlated to the findings of an abrasion and pulpy swelling noted by the MO in the field, it was concluded that the probable cause of death was severe head injury.

Discussion

The Sukhoi 7B fighter aircraft was equipped with an ejection seat which could be used in three positions: low, medium and high. Pilots with high sitting heights (sitting height is the vertical distance between the base of the spine while sitting erect on a hard surface, and the top of the head) were advised to use either the medium or the low position depending on their "eye datum" line which was marked in the cockpit.

If a pilot had to eject from the aeroplane, the canopy of the aircraft would slide backwards over the pilot's head and leave the aircraft at its rear end. If the pilot sat in a position which was too high for him, there was the strong possibility that the leading lower border of the canopy would strike his forehead as it slid over him.

The pilot, Flying Officer V, had a high sitting height and had been advised to fly in the low seat position. The possibility of his head being fouled by the canopy while ejecting had been demonstrated to him; however, he had chosen to use the high seat position because he found the bomb sight and the front gun sight easier to operate in the high position.

Given this information, the possible sequence of events may be reconstructed. The pilot was flying as per his practice in the "high" position which was inappropriate for him. When he initiated ejection (once initiated, the ejection sequence, which occurs in less than a second, can not be arrested) the canopy which weighed approximately 60kg, was jettisoned by the explosive charge, developing extremely high kinetic energy. It slid backwards along the cockpit, and as it was about to leave the aircraft from the rear of the cockpit its leading edge struck a hammer blow on the forehead of the pilot. This accounted for the dent seen on the frontal region of the helmet which had taken the shape of the lower ridge of the canopy. The impact jolted the pilot's head backward striking the head rest of the ejection seat so denting the back of the helmet covering the occipital region. Both the impacts, which probably occurred in about 200-300msecs, were enough to produce a fatal head injury as noted by the army doctor in the battle zone.

Conclusion

The correlation of head injury of the pilot to the various marks on his helmet was strong enough evidence to prove that he had fouled the canopy fatally as he tried to eject from the aircraft. As per the classical definition,[1] this incident may not be classified as an accident as it happened indirectly as a result of enemy action during operations. Nevertheless, such an event was inevitable when the pilot chose to fly in a position which would compromise his flight safety. If he had chosen the prescribed seat position, he would probably have made an uneventful escape from his aircraft. It was thus the attitudinal error [Figure 1] of the pilot which led to this uncalled for incident. No other failure on the part of the pilot was responsible for the event. It is for this reason that it has been classified as an accident.

Case Report Two

Two Sukhoi 7B fighter aircraft were detailed to undertake a low level high speed navigation sortie (flight). The aim of the mission was to familiarise the newly posted flight commander of the squadron, who had a considerable amount of recent flying experience on Hawker Hunter fighter aircraft, with the Sukhoi aircraft. The flight was led by No 1. pilot who, though junior in rank to his flight commander, was experienced on the Sukhoi and had been flying in the area for about two years. The flight commander was No. 2 in the formation [Figure 2]. The sortie progressed as planned until the last part of the exercise. In this, the aircraft were to simulate a dummy attack on an imagined target. Both aircraft, with No. 1 in the lead, were to "pull up " rapidly from their flight altitude of about 100 meters above ground level to about 2 km, dive towards the imagined target, and then pull gradually out of the dive and resume the low level course. In flying terminology, this is known as a loop followed by a dummy dive [Figure 2]. Accordingly, the section leader (No. 1) initiated the manoeuvre into which both the aircraft entered. A few seconds later No. 2 crashed fatally into the ground.

Discussion

Both pilots had been declared medically fit to fly by the Squadron Flight Surgeon during the routine pre-flight medical examination. The sequence of events as per an eye witness account of the lead pilot was as follows. The aircraft were airborne at around 0800 hours on a warm April day, and set course for the designated flying area as per the pre-flight briefing. Towards the end of the mission, No. 1 "pulled up" to go into ground attack mode as shown in Figure 2. He completed his manoeuvre and when he was on the descent he saw his No. 2 also reach the top of the loop. However, after that the lead pilot noticed that the No. 2 aircraft seemed to be out of control and started to "fall out of the sky". He called the pilot, but got no response. Within 15-20 seconds, he saw the aircraft hit the ground on its belly and burst into flames. The pilot had made no attempt to eject. No. 1 also stated that just before the aircraft finally hit the ground, he may have heard some sort of a grunt on his radio transmitter. He reported the accident to the air traffic control and returned to base.

The rescue team found the crashed aircraft had landed on its belly and was almost completely burnt. The cockpit had been destroyed. The pilot

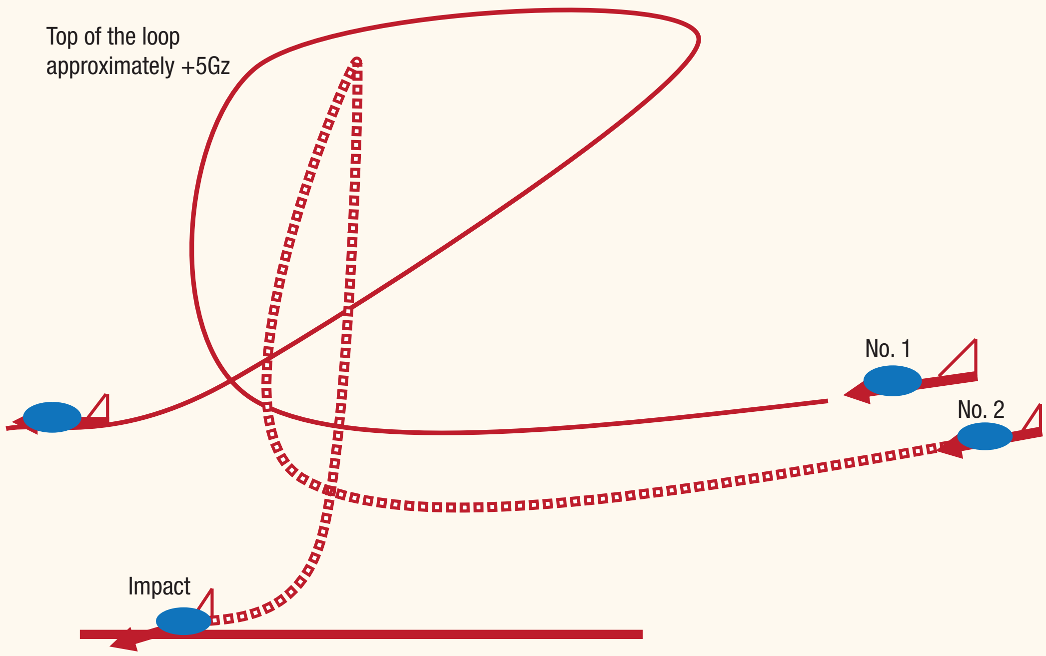

Figure 2: The construction of the flight profile which may have led to the fatal crash because of possible pilot incapacitation due to a gravity-induced loss of consciousness (G-LOC). Note the figure is not mathematically accurate.

had also almost burnt to ashes, and only a few of his remains could be identified. His flying clothing was burnt, and the helmet had melted. The aircraft had not exploded. There was no evidence to indicate aircraft malfunction and this was corroborated later by a technical investigation. Body parts/tissue were not available for a postmortem examination.

During a loop manoeuvre, the pilot experiences effects of +Gz (positive acceleration) which drives the blood column towards the lower part of the body thus reducing perfusion to the brain. Autonomic reflex activity is brought in to play to restore the brain circulation. This reaction takes between 5-7 seconds to be established in a normal individual.[4] The reflex response may found to be wanting in a number of circumstances such as heat stress, hypoxia, medication with centrally acting drugs, use of antihypertensives, and consumption of alcohol.[5] The response may also be affected adversely by the magnitude and the rate of application of the +Gz force. The contribution of circadian rhythm effects contributing to the pilot's incapacitation is ruled out as the flight was launched in the morning as per the routine operations schedule. The pilot had not been flying late into the preceding night. Hence he had not altered his routine circadian rhythm. There was no history to suggest that he had indulged in any other activity that may have altered their night-day physiologic cycle. In fact, it has been suggested that cardiovascular reflex activity may be functioning at its peak during the morning hours.[6] Hence the scheduling of the flight in the morning should have enhanced his performance.

In the manoeuvre undertaken [Figure 2], the magnitude of the stress is usually about +5Gz, and is considered within tolerable limits for a trained fighter pilot. The rate of application may vary, but pilots usually control it to less than 1 Gz/sec in a planned manoeuvre as undertaken in this case. The manoeuvre was successful until No. 2 had almost reached the peak of the loop, a point at which the maximal +Gz stress is felt. For unexplained reasons, it may be presumed that the pilot then suffered a gravity-induced loss of consciousness (G-LOC) which incapacitated him.

The aircraft in question was not equipped with an in-flight data recorder (the so-called black box). Hence it was not possible to establish whether the pilot had inadvertently applied a +Gz force in excess of the usual tolerable limits.

From the available documents, it appears that he had not been grounded at any time in his career, nor was he taking any medications; however, consumption of unprescribed medications, such as antihistamines, or tranquilisers, cannot be ruled out. Such medications are known to affect tolerance to + Gz stress.[5] He was reported to have put on the anti-G suit before getting into the cockpit. It may be argued that for unknown reasons, he did not connect the suit to the aircraft system, and hence did not get the protection against the Gz force which the G-suit offers. This in turn may have led to the G LoC.

April mornings in the north of India are often quite warm. The ambient temperature at the time of the sortie was around 27^{O}–28^{O}C. During high speed low level flight, aerodynamic friction is known to increase the cockpit temperature by about 8–10 C.[7,8] Therefore at the time of the manoeuvre, the cockpit temperature may have been around 36–38 C, and would have been so for about 20–25 minutes before the episode. Whole body heating causes vasodilatation with sweating as a heat dissipating mechanism. It is possible that No. 2 reacted to the increase in cockpit temperature with these mechanisms, and the mild dehydration and peripheral vasodilatation aggravated the adverse effects of +Gz stress and induced the G LoC.

There are two phases of G LoC: 1) the stage of complete incapacitation which lasts for about 12–16 seconds. This is followed by a period of mental confusion and partial incapacitation during which consciousness is partly regained, but the pilot is incapable of performing useful tasks. This phase may last or another 12–15 seconds.[9,10,11] Therefore, after suffering a G LoC, a pilot is not in control of the aircraft for as long as 25–30 seconds. In the case under discussion, No. 1 had estimated that 15–20 seconds had elapsed from the time he noticed that No. 2 was not in control to the time he crashed. The possible grunt he heard before impact may have been the sounds made in the cockpit by the partially conscious No. 2. Given the time frame of recovery from G LoC, this may have happened before any perceivable recovery had occurred. It may be presumed then that, at time of impact, No. 2 had just about regained partial consciousness and he died because of the crash impact and the post crash fire. If the episode had occurred at a much higher altitude, the pilot might have been able to regain control of his aircraft.

In-flight spatial disorientation (SD) has been associated with partial or total pilot incapacitation resulting in an accident.[1,3] In the case under discussion, the weather at the time of flight was clear, devoid of clouds, or poor visibility which are often the contributing factors to SD. The manouevre performed by the pilot was not one which would have caused stimulation of more than one set of semicircular canals or the otoliths to generate conflicting vestibular sensations which might have progressed to SD.[12] The pilot was fit to fly on the day of the accident, and there was no reason to suspect the presence of vestibular pathology. This rules out the occurrence of in-flight disorientation as a cause of the fatal accident.

Conclusion

On the basis of circumstantial evidence, it is postulated that the accident occurred because the pilot had become incapacitated during the flight. There is a strong likelihood that this happened because his physiological mechanisms failed to sustain brain perfusion when he went in to a loop manoueuvre.

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