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Experiential learning using case studies of aircraft accidents in aviation meteorology courses

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ABSTRACT: The year 2007 was a good year for aviation safety worldwide but there were more aircraft accidents than usual in South America and South East Asia. In South East Asia, there were three accidents in Indonesia and one in Thailand. In the Thailand accident and one accident in Indonesia, it has been suggested that an isolated weather event or a meteorological phenomenon, during the critical approach and landing phase of flight, caused the aircraft to crash, leading to a large loss of life. The use of case studies of these events in the aviation meteorology course is discussed in this article. This will involve an analysis of the weather condition prevailing at the time of the accident and the pilots' actions and, more importantly, discussion of the correct actions that should have been taken. Re-enactments were undertaken by groups of students in simulated conditions, in an experiential learning environment, in order to increase awareness of the problems associated with adverse meteorological events that occurred in these particular accident case studies.

INTRODUCTION

Weather-related aviation accidents, in both large and small aircraft, still remain one of the most significant causes for concern in aviation safety today, despite all the research and development which has been carried out over the last hundred years since the Wright Brothers first flew at Kitty Hawk Field.

Accident and casualty statistics show a steady downwards trend in the number of accidents per year from approximately 1972 [1]. The accident records show that 2007 was a particularly safe year. In fact, 2007 was the second safest year since 1942 for airline accidents. In 2007, a total of 26 fatal multi-engine airliner accidents occurred. This resulted in 750 fatalities and 41 ground fatalities. The average for the ten year period from 1997-2007 was 34 fatal accidents, resulting in 914 fatalities [1]. A graph of airline accidents and casualties from 1942 until 2007 can be seen in Figure 1. Figure 1 also shows that 2003 was the safest year on record in terms of airline accidents. This steady decreasing trend in the number of airline accidents is despite the increase in passenger miles and in the context that growth in the aviation industry is expected to be approximately 3-5% per year [2].

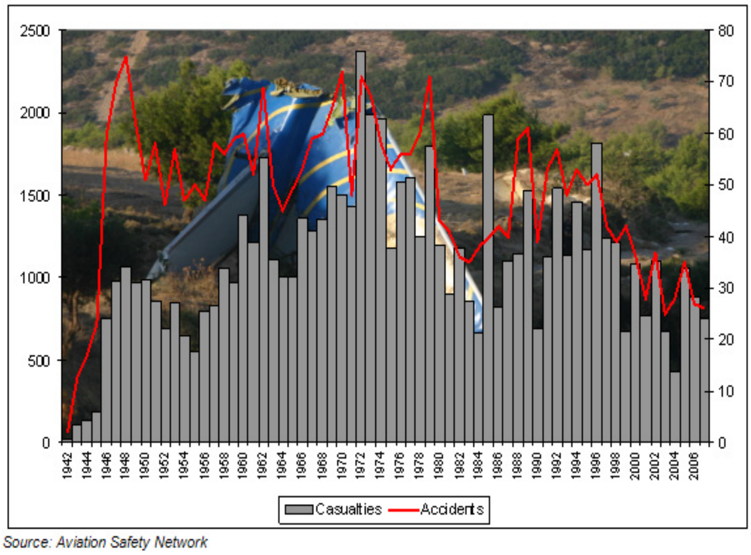

Figure 1: Aeroplane accidents from 1942 through to 2007 [1].

The year 2007 was not a good year for aviation safety in South America or South East Asia. Indonesia had a very bad year in 2007 with two fatal accidents and a non-fatal one. On New Year's Day an Adam Air 737 crashed at sea killing 102 people and on 21 February, another Adam Air 737 landed hard on the runway at Surabaya-Juanda Airport. On 7 March, a Garuda 737 overran runway 09/27 at Yogyakarta-Adisutjipto Airport skidding through the perimeter fence and ending up in a rice paddy. The airplane then caught fire causing the death of 21 people.

Brazil had another fatal accident for the second consecutive year when on 17th July an Airbus A320 of TAM skidded on the slippery runway after landing at Congonhas. The cockpit voice recorder transcript indicated that the spoilers did not activate after touchdown. After touching down the A320 became airborne, cleared the perimeter fence and a busy highway and collided with a concrete building, bursting into flames killing all passengers and crew and 12 people on the ground [1].

Weather may have played a significant part in these accidents, however, despite the rapid technological advances in the forecasting and displaying of severe weather hazards, such as icing, turbulence, lightning and wind shear. Weather continues to be identified as a major causal factor in many accidents and incidents, which occur in all forms of flying.

WEATHER RELATED ACCIDENTS

> *On 16 September 2007 at approximately 1600 local time, One-Two-Go flight 269, a Boeing-McDonnell Douglas MD 82 overran runway 27 as it attempted a landing at the Phuket International Airport after a flight from the Thai capital, Bangkok. There were 89 fatalities from a total of 123 passengers and 7 crew members who were on board* [3].

High wind and driving rain was reported at the time the MD-82 attempted to land and subsequently skidded off the runway. It ran though a low retaining wall then broke into two parts and caught fire engulfing some passengers. The visibility was reported to be very poor at the time the pilot attempted to land the aircraft. Whilst the cause of the accident has not been officially determined, it is believed that wind shear may have been a strong contributing factor. Wind shear has been a factor in many aircraft accidents over the years for both large and small aircraft.

Another passenger plane

> *…carrying 102 people disappeared in stormy weather on Monday, 1 January 2007. Adam Air Flight KI-574 was on a two-hour flight from Indonesia's main island of Java to Manado, on the northern tip of Sulawesi, one of the largest islands in the archipelago. Just over half of the flight path was over the Java Sea, the Maluku Sea and other smaller bodies of water, with the remainder over Sulawesi Island* [4].

Turbulence and windshear was a possible factor in yet another accident in 2007.

> *Adam Air Flight 172 was a serious incident involving a Boeing 737-300, registered PK-KKV, flying on a scheduled domestic passenger flight in Indonesia Between Jakarta and Surabaya. On February 21, 2007, the plane bent on landing, with the fuselage cracking in the middle of the passenger section* [5].
>
> The aircraft was *…damaged beyond economical repairs today 21-02-2007 in a very hard landing in Surabaya, Indonesia. Preliminary info says windshear could be involved. The fuselage broke in two near the wings attachments* [6].

The three accident examples above are but a small part of a long list of accidents and incidents where wind shear and turbulence have been cited as possible causes.

WIND SHEAR AND TURBULENCE

With regard to aviation, wind shear is defined as *variations in the wind along the aircraft flight path of a pattern, intensity and duration that displace an aircraft abruptly from its intended path such that substantial control action is required* [7].

Turbulence is similar to wind shear in that it can disturb the aircraft’s attitude about its major axes but it does not tend to displace the aircraft from its intended flight path. They can be both transient and sporadic. Graphic evidence of a change to the intended path of an aircraft, which has encountered strong wind shear and turbulence during the landing and take-off sequences, has been captured on film on a number of occasions.

Significant wind shear is usually associated with such meteorological phenomena as thunderstorms (gust fronts and microbursts), high and low level jet streams, winds blowing across uneven terrain (terrain-induced wind shear) and sea breeze fronts. Shears associated with thunderstorms are the most hazardous, particularly to an aircraft during the take-off or landing phase, when it is close to the ground. In any strong wind condition there will be appreciable shear between the free flowing air above the friction layer and the retarded flow in the friction layer, close to the ground. This is the normal situation, therefore, close scrutiny of the forecast winds will enable the pilot to anticipate and allow for possible wind shear during the take-off or landing sequence. Wind shear can be vertical between layers of the atmosphere or it can be horizontal, where two air masses meet. It can also occur between air masses moving at different speeds. *Thunderstorms often develop localised rotation (vorticity) due to wind shear in the vertical. Wind shear between atmospheric layers is thought to produce rotation around the horizontal axis, which is then tilted upward by the strong updraughts within the developing storm* [8].

Wake flows induced by terrain obstacles can, if the wind is strong enough, become very turbulent for considerable distances downstream. These structures known as von Karman Vortex Streets are *common over mountain ranges, and the wake can be felt up to 100 kilometres downstream* [9]. Vortices in the wake of a hill or a building can produce updrafts, downdrafts, as well as horizontal eddies, causing an aircraft to be buffeted in any direction. Wind speed increases as the distance from the earth's surface increases, so as the faster airflow at height wraps around the obstacle, a horseshoe vortex can be produced which has a downstream circulation pattern similar to trailing vortices [9]. The chaotic turbulent wake can be further destabilised by buoyant convection produced by terrain, which has been heated during hot summer weather. These downstream vortices can be both dangerous and unpredictable to aircraft operating in these regions.

Thunderstorms can also produce very violent downdrafts known as microbursts. These downbursts are very dangerous and have been the cause of many aircraft accidents and incidents over the years, and generally occur with thunderstorms originating in warmer climate areas. It is the very rapid change in wind speed and/or direction, which poses a real threat to an aircraft on its landing approach or on take-off. Close proximity to the ground leaves very little safety margin for recovery and a safe touchdown.

> *If a downburst occurs over an airport during take-off the aircraft first encounters a strong headwind that is the laterally spreading section of the downburst, then a downdraft, which is the vertically descending section of the downburst, an finally a region of strong tail wind. During landing the aircraft flies into a strong head wind then enters a region of strong downdraft before encountering a strong tail wind* [10].

Typically these microbursts have a horizontal dimension of 1-4 kilometres and a lifetime of between 5 and 15 minutes. Microbursts tend to intensify in the first 5 minutes after the downdraught impact with the ground. *The average wind differential (i.e. head-wind to tail-wind shear) for an aircraft in flight through a microburst was found to be 25 m* s^{-1} *(about 50 kt) and the maximum 48 m* s^{-1} *(about 93 kt)* (Great Britain Meteorological Office) [7]. Identification of the microburst as a factor in a number of fatal air accidents has prompted ongoing research into methods of detection.

A low-level wind shear alert system (LLWAS) has been produced, which can detect sudden changes in wind velocity from an array of strategically sited sensors in the vicinity of the airfield. For example, aircraft using the Hong Kong International Airport (HKIA) are provided with a wind shear and turbulence alerting service by the Hong Kong Observatory (HKO). The wind shear and turbulence experienced by an aircraft may vary in intensity considerably in a short space of time, so that reports from other aircraft in the area and the alerts issued may be incorrect at that moment.

> *Over the seven years (July 1998 – June 2005) since the opening of HKIA, about 1 in 500 arriving and departing flights have reported significant wind shear. Over the same period, around 1 in 2,000 flights have reported significant turbulence. A majority of these events were reported in the Spring months of March and April* [11].

EDUCATIONAL METHODOLOGY

Given the descriptions of severe meteorological event above, it is obvious that a pilot must remain aware of their meteorological environment at all times and understand the significance of any weather changes, however subtle, which may occur on the take-off or landing phase of flight. In the aviation meteorology courses at the University of South Australia (UniSA), strong emphasis is placed on an understanding of the ever changing weather profile and the pre-requisite factors for the development of severe conditions. With an understanding of these processes comes the potential for a reduction in the types of weather accidents and incidents through a more careful and considered approach to each situation encountered.

As the students progress through the Integrated Program at UniSA, the theory learned in the classroom is related to practical situations which may occur to an aircraft whilst in flight. Methodologies such as case studies and re-enactments of documented accidents or incidents are undertaken. The case studies are often very dramatic and from open-ended questioning of participating students, it is something which is well remembered. The conclusion is that the re-enactments, researched and presented in student groups, have proved to be a very effective learning strategy. Former students have often remarked on the usefulness of these presentations as a reinforcement of their learning and specifically on their relationship with so many of the practical aspects of aviation. The learning/teaching strategy is a combination of relating the theory to the practical aspects of flying and developing an understanding of the processes involved, particularly with less benign meteorological phenomena. This is essential to a safe and uneventful flight.

It is customary to begin each meteorology lecture at UniSA by examining and analysing the current weather information, and to look for conditions which were similar to those present, when an accident or incident occurred somewhere around the world. Repeated exercises such as this serve to reinforce, especially to inexperienced student pilots, the value of constant awareness and understanding of meteorological events.

It also emphasises that the type of local topography can substantially change the nature and strength of weather systems. This interaction, which can occur between the weather and the local topography, is generally not something which is shown on an aviation forecast and, therefore, its significance is easily missed by both inexperienced and experienced pilots.

Graphic videos, CDs and DVDs are also used to help the student relate the practical aspect with the theory. This helps considerably with the early recognition of weather situations, which may change and develop to the point where it is too late to take avoiding action, often with disastrous consequences.

EXPERIENTIAL LEARNING

The word experiential suggests that learning of itself is not complete without experience as a concrete foundation on which to build useful learning. Experiential learning, for a large part of the twentieth century, was basically thought to be the domain of the less academic student, who did some technical training as a preparation for a manual type of occupation. Carl Rogers identified two types of learning:

> *…cognitive (meaningful) and experiential (significant). The former corresponds to academic knowledge such as learning vocabulary or multiplication tables and the latter refers to applied knowledge such as learning about engines in order to repair a car. The key to the distinction is that experiential learning addresses the needs and wants of the learner* [12].

The Civil Aviation students at UniSA usually have very clear and precise needs and wants. They are very enthusiastic about putting into practice the material which they have learned in the classroom, so for this reason there needs to be an integrated approach with the theory and practice as far as is possible.

Around 450BC Confucius is reputed to have said: *Tell me and I will forget; show me and I may remember; let me do and I will understand.* Experiential learning is very much an active rather than a passive process. Kolb describes learning as a four-step process, and identify the steps of the process as *concrete experience, observation and reflection, the formation of abstract concepts and testing in new situations* [13]. Kolb argues that the learning cycle can begin at any one of the four points - and that it should really be approached as a continuous spiral [13].

However, it is suggested that the learning process often begins with a person carrying out a particular action and then seeing the effect of the action in this situation. Following this, the second step is to understand these effects in the particular instance so that if the same action was taken in the same circumstances, it would be possible to anticipate what would follow from the action. In this pattern the third step would be to understand the general principle under which the particular instance falls. Dewey believes that *...Experiential learning takes place when a person involved in an activity looks back and evaluates it, determines what was useful or important to remember, and uses this information to perform another activity* [14].

Towards the end of the aviation meteorology course at UniSA, the students divide into several small groups and plan a re-enactment of an aircraft accident in which a severe meteorological event was a major causal factor in the accident (Figure 2). The students carefully research the event, then re-enact it using such things as mock-ups and models of the aircraft and the environment, a computer simulator, the actual weather forecast details which would have been obtained by the flight crew, video clips, sound effects and the transcripts of the aircraft cockpit voice communications. These, often very graphic re-enactments, are played out in front of an audience of their peers.

The students look particularly at the circumstances which led up to the accident and how the progression of events finally culminated in the accident itself. This progression of events is examined in terms of James Reason's *Swiss Cheese Model* of system failure, where each failure or error, whilst not in itself catastrophic, finally align to produce a fatal result [15]. They also look at the details of the official accident report and explain the details of how the weather phenomena developed, what were the pre-requisites for this weather situation to occur and how early in the flight these indicators were first noticed.

This experiential learning method of *let me do and I will understand*, is an exercise that the students always remember and, more importantly, it triggers their memory when confronted with similar real life situations.

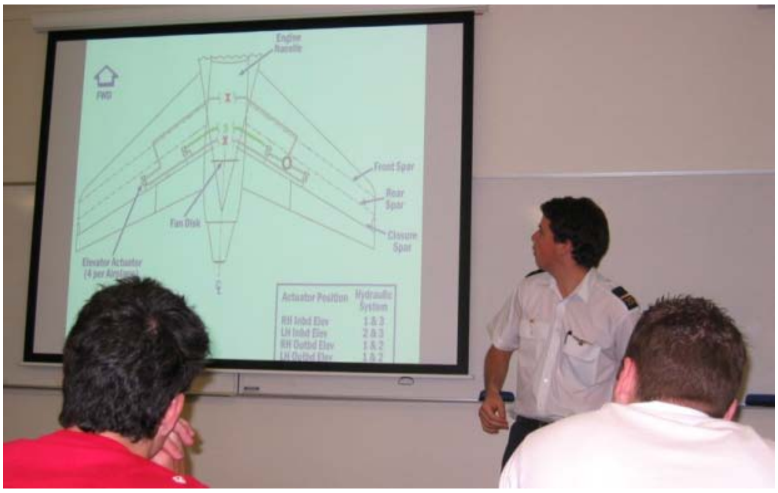

Figure 2: Explaining the facts during a case study re-enactment.

CONCLIUSION

The experiential learning gained through re-enactments is an essential and rewarding experience, which allows the students to feel comfortable with the fact that they can successfully learn and do, and do correctly, with confidence and accuracy. Based on student feedback during group analysis following the re-enactments of topical and current weather related accidents, it appears that students' awareness and understanding of severe weather phenomena is much improved.

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