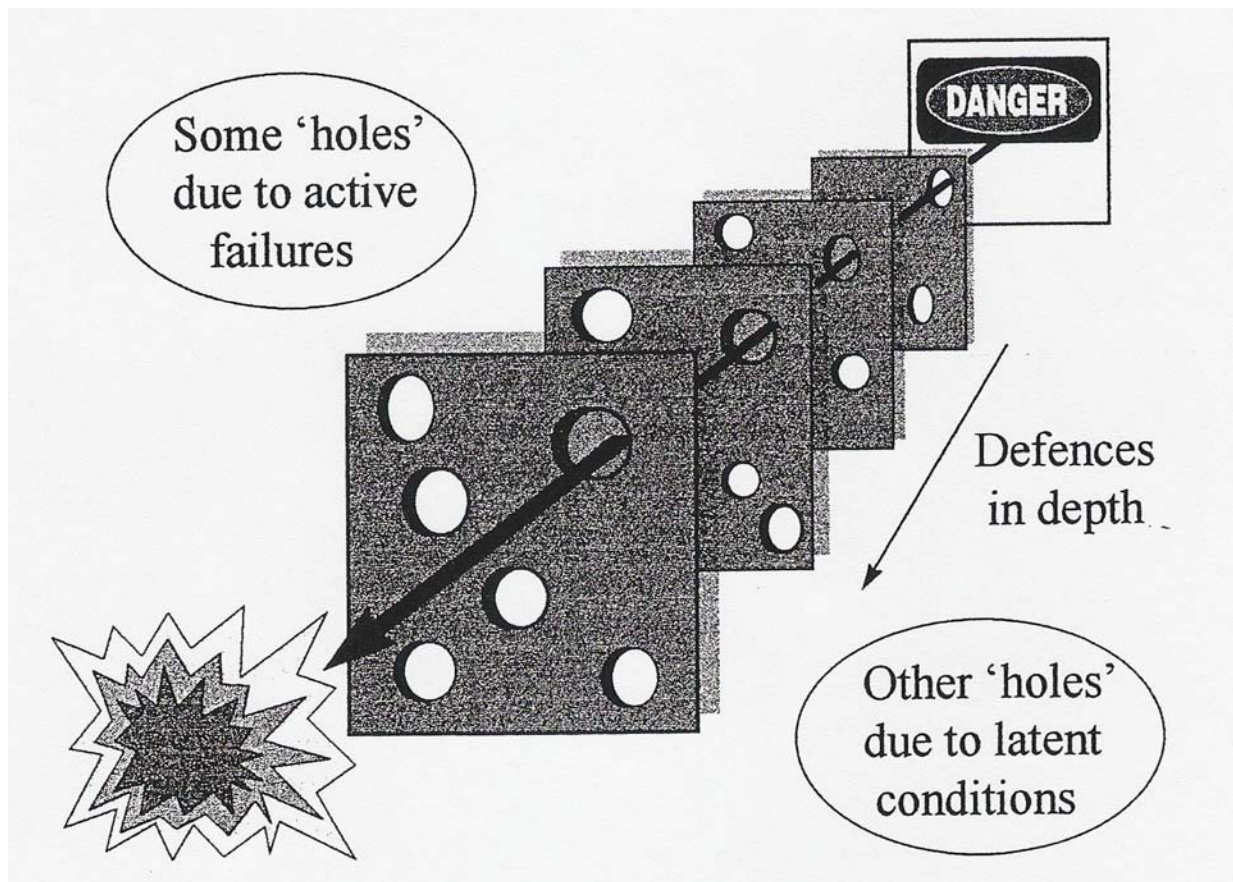


Accidents, Failures, Mistakes and Leaky Buildings



Accident, mistake, failure
or leaky building

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Executive Summary

This paper examines the causal factors of accidents and failures in two totally different contexts; Air New Zealand's Erebus plane crash which occurred over 25 years ago and the Leaky Building Syndrome which is a multi billion dollar problem that continues to plague many New Zealanders.

The work of causation thinkers such as James Reason and Sydney Dekker is discussed and their failure models are applied to these two case studies.

The Erebus plane crash and the Leaky Building Syndrome are both organisational accidents with multiple causes and although they are grounded in totally different contexts and timeframes, their causal factors nonetheless have remarkably similar features which can be used to prevent organisational accidents in other contexts if these are understood.

This paper highlights the need to subject organisational accidents and failures to comprehensive analysis, without which future recurrences may not be prevented. Regrettably, some aspects of modern accident and failure analyses do not respond well to conventional legal processes.

Introduction

As individuals we struggle with our human condition. We strive to create and advance our lot without making mistakes or failing, but all we can do is trade large mistakes for small ones, using these or the absence of these to define and validate our experience so that we may then use them for the benefit of others. When a large accident occurs, we refer to our own individual experiences as a template for trying to understand the cause of these large accidents and naturally assume that there is always a 'root cause' and a single person or entity to blame.

However in my experience as an accident investigator, there is seldom a root cause and contrary to initial appearances, there are often many significant contributing causes which can be generated within the depths of an organisation or regulatory body. Although there are some accidents which are caused by single individuals alone, most are what modern analysts term "organisational accidents" which have multiple causes involving many people operating at different levels of their respective companies. Regrettably however, corrective discipline is often more readily applied to individuals than organisations.

Over the past two decades there has been much work undertaken by behavioural researchers in this field. Interestingly, the investigation into the Erebus crash by Captain Gordon Vette and High Court Judge Peter Mahon, has contributed internationally to the understanding of how organisational accidents occur and it is appropriate that we begin our study by understanding not only the contributing causes of the Erebus crash, but also the difficulties in investigating it.

Erebus

On the 28th of November 1979, a DC10 operated by Air New Zealand crashed on the northern slopes of Mt Erebus, while conducting a sightseeing flight to the Antarctic. All 257 people on board died instantly. This emerged as one of the world's first acknowledged "organisational accidents" of significant magnitude, that is, an accident that had been caused by various elements of an organisation without any one person to blame.

ICAO, the International Aviation body responsible for regulating and setting International Air standards stated in its Human Factors Digest No 10:

“The Erebus report... generated violent controversy and remained inconspicuously shelved until recently... In retrospect, if the aviation community-and the safety community at large-had grasped the message from Antarctica and applied its prevention lessons, Chernobyl, Bophal, Clapham Junction, King’s Cross... would not have existed” (Vette & Macdonald, 1999, pg. 3).

The Erebus accident was first investigated by the office of Air Accidents of the Civil Aviation Division (CAD) of the Ministry of Transport, which attributed the cause of the accident to the aircrew descending below the minimum safe altitude of 16,000 ft and continuing the flight below this altitude in poor visibility towards Mt Erebus when they were unsure of their position (Vette & Macdonald, 1999). Although the poor visibility was attributed to whiteout conditions, the CAD report strongly inferred that the pilots knew that they were flying in poor visibility. The CAD report therefore proposed an individual cause.

Before the CAD report was published, the New Zealand government commissioned a Royal Commission of Inquiry headed by Justice Peter Mahon, to more thoroughly investigate the crash and possibly to ‘rubber stamp’ the CAD report. However Peter Mahon’s findings disagreed with the CAD report and not only cleared the flight crew from blame but transferred the blame to Air New Zealand, accusing Air New Zealand management of conspiring to lie, and quoted the famous “litany of lies” comment. Mahon accused several Air New Zealand witnesses of perjury.

From cockpit voice recordings and photographs taken by passengers moments before the crash, Justice Peter Mahon with the aid of Captain Gordon Vette, was able to conclude that the weather was fine at the time, visibility was good, and Mt Erebus was not shrouded in cloud. The pilots who were flying the aircraft did not see the mountain in front of them, even though atmospheric visibility was 40km. They could see a horizon (albeit probably a false one) and were in clear sight of ground

and water beneath them, but could not see Mt Erebus which they were about to fly into.



Figure 1: Cabin Sunlight. Two photographs developed from passenger film showing cabin bathed in sunlight moments before impact, indicating fine weather and good visibility. (From Impact Erebus II, p. 65)

Moreover the company had altered the course that was programmed into the aircraft's navigational computer without advising the captain of the change. Peter Mahon judged this as the primary cause. Originally the course had them flying into McMurdo Sound which in whiteout conditions looked very similar to Lewis Bay at the foot of Erebus and which they over-flew just before impact. Vette (1999) showed that they had developed a mindset which interpreted geographical features and the scenes around them in relation to McMurdo Sound, not Lewis Bay and Erebus. This mindset in conjunction with the whiteout phenomenon that rendered Mt Erebus invisible, allowed them to mistake their true position, fail to see the mountain in clear air ahead of them and crash into it.

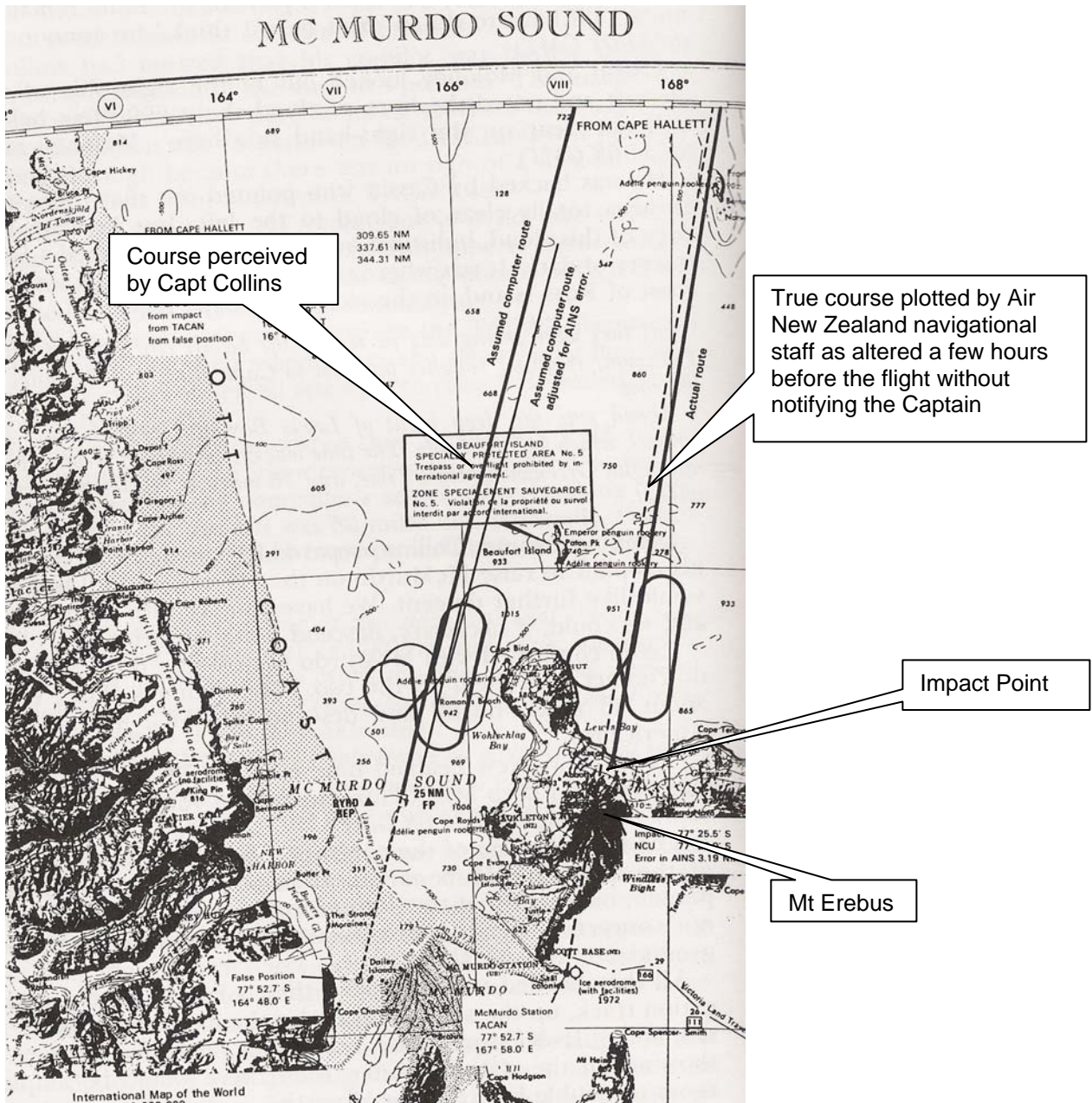


Figure 2: The perceived and true courses of flight TE901. (Reproduced from Impact Erebus II, p134)

How the pilots saw Mt Erebus

How McMurdo Sound would have appeared

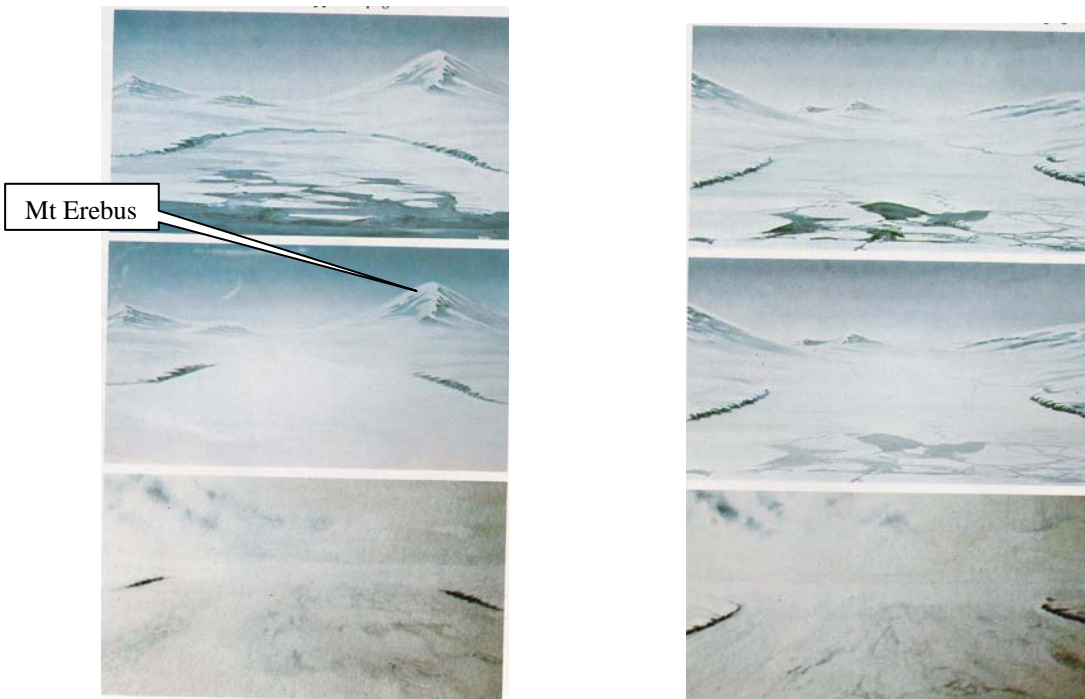


Figure 3: The pilots' view of Lewis Bay and McMurdo Sound. The similarity of Lewis Bay and Mt Erebus in whiteout conditions with McMurdo Sound. (Impact Erebus II, p78, 79)

In terms of the history of human factors science, this was significant. Not only did they not see the mountain, but they could not see that they couldn't see it. They were unfamiliar with sector whiteout conditions, which provided visual depth perception for only part of their field of view, tricking them into thinking that they could see correctly throughout all of it.

Mahon (1981) cited ten factors which contributed to the crash, any one of which could have prevented the accident had it not occurred. The ten factors were:

1. The captain had complete reliance on the accuracy of the aircraft's navigation system
2. The captain was not supplied a topographical map showing the programmed navigational track on the topographical map
3. The captain plotted the track himself on an atlas the night before the flight

4. The track of the last leg of the flight path was altered six hours before the flight departed
5. None of the flight crew were told of the alteration
6. In-flight checks verified the accuracy of the aircraft's navigational system
7. McMurdo Air Traffic control believed that the aircraft would approach down McMurdo Sound, not over Mt Erebus
8. Mac Centre invited the aircraft to descend to 1500 ft in McMurdo Sound because visibility was 40 miles or more
9. The Captain accepted this invitation and made the decision to descend to that altitude
10. The nature of the cloud base in Lewis Bay and the whiteness of the snow beneath the overcast cloud cover combined to produce the whiteout visual illusion.

Of these ten factors, item two was blamed on CAD and items two and five were blamed on the airline with item five being considered the main cause. That is, Mahon judged the primary cause to be the act of the airline in changing the computer track of the aircraft from McMurdo Base to Mt Erebus without telling the aircrew (Mahon, 1981). He also uncovered an organisational structure with poor communication and administration procedures that contributed to the main cause.

Mahon also blamed the airline for deliberately conspiring to lie, reflected in his famous 'litany of lies' quote. Air New Zealand objected to the Court of Appeal (CA) on the basis of costs. According to historical clauses in the TAIC Act, the CA judged that Mahon overstepped his brief in judging that the Air New Zealand witnesses committed perjury, because it was a crime and could only be judged so in a court of law, not a Royal Commission of Inquiry (Beck 1987). However the Court of Appeal stopped short of faulting Mahon's technical determinations including the predominant cause of the crash.

Mahon appealed to the Privy Council as a private citizen but the Privy Council not only supported the Court of Appeal, it also cleared the airline of blame without the corresponding rigour of Mahon's enquiry. This effectively undid much of Mahon's

work and to a layperson, confused the findings. The logic of the Privy Council in clearing the airline of blame remains unclear. The judgement of the Court of Appeal and Privy Council is criticised by Stuart MacFarlane, a retired senior law lecturer, in his book titled *The Erebus Papers* (1991). According to MacFarlane (1991) and Beck (1987), in order for Mahon to judge between conflicting witnesses, he had to judge that several of them had lied and could not fulfill his mandate without judging so. In their view, this would have been obvious to the alleged liars and the warning that the Court of Appeal and the Privy Council judged should have been given, was unnecessary.

Beck (1987) cites that the main reason to go to appeal was in order to vindicate Air New Zealand of its reputation. Therefore without Mahon's mandate to apportion blame, Air New Zealand may not have appealed and the investigation process may have concluded with a clearer outcome. It is interesting to note that during the course of Air New Zealand's final submissions, when it was convenient for them to do so, counsel for the airline invited Mahon to stop short of attributing blame and merely identify the contributing factors. In response, Mahon acknowledged that "the prime purpose of aircraft accident investigation is to secure avoidance of similar accidents in the future, not to identify and apportion culpability or blame for what occurred" and that citing the ten factors was sufficient to achieve this (Mahon, 1981, p. 158). However he advised that his mandate also included the need to "answer the question whether this disaster was caused or contributed to by blameworthy acts or omissions by any person or persons" (Mahon, 1981, p. 158).

The cost of a clouded inquiry and the need to apportion blame was enormous. Following the inquiry, Captain Gordon Vette and Peter Mahon, both leaders and highly respected professionals in their respective fields resigned from their jobs, thus ending their careers. Although Captain Vette continued to implement improvements in international air safety, regrettably Mahon died a few years later. In the minds of many professionals, the judgement of the Privy Council confused the conclusions that Mahon so painstakingly derived and made it difficult for safety professionals to openly promulgate the lessons learnt from the Erebus crash, which ICAO later admitted carried a profound message in preventing organisational accidents in the future. If the lessons from Erebus may have prevented Chernobyl and Bhopal, then

they could have also prevented today's Leaky Building Syndrome. However, although we may not have fully grasped all the lessons from Erebus, accident causation thinkers such as Gordon Vette and James Reason did.

Modern Accident Causation Theories

About ten years after Erebus, Professor James Reason documented his theories on error by referring to organisational deficiencies, latent and active errors (Reason, 1990). Latent failures are often caused by people such as decision makers, managers and regulators well before an accident but with consequences that may lie dormant for some time until active failures or other events trigger them. Active failures are errors and violations with immediate adverse effects that often have close links with individuals or the last stages of the accident timeline and which often attract the interest of legal and insurance processes.

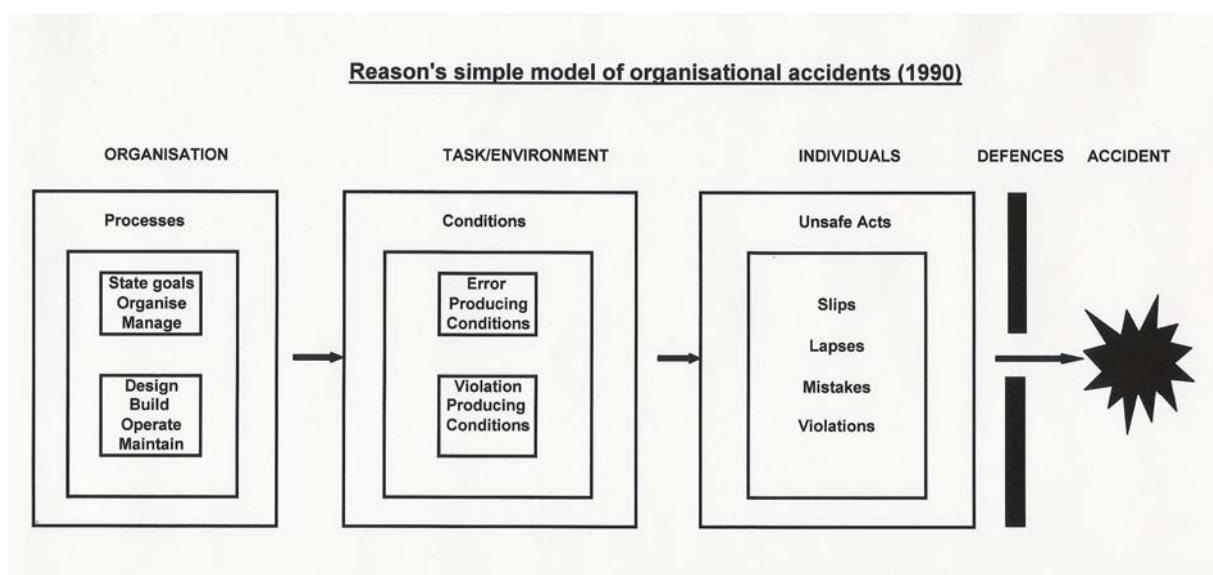


Figure 4: Reason's model of Organisational Accidents

In 1997 Reason published his book titled “Managing the Risks of Organisational Accidents” and included both Captain Vette and another causation thinker, Captain Meurino in his short list of dedications at the front of his book. (Captain Meurino worked for ICAO and was responsible for writing the Human Factors digest No 10 quoted earlier.) The book includes what is now referred to as the “Swiss Cheese” accident model. This model portrays the accident timeline as an arrow that penetrates successive defences until an accident occurs. These defence deficiencies

are compared to the holes in several layers of Swiss Cheese which all must line up coincidentally for an accident to occur, as shown in figure 5 below.

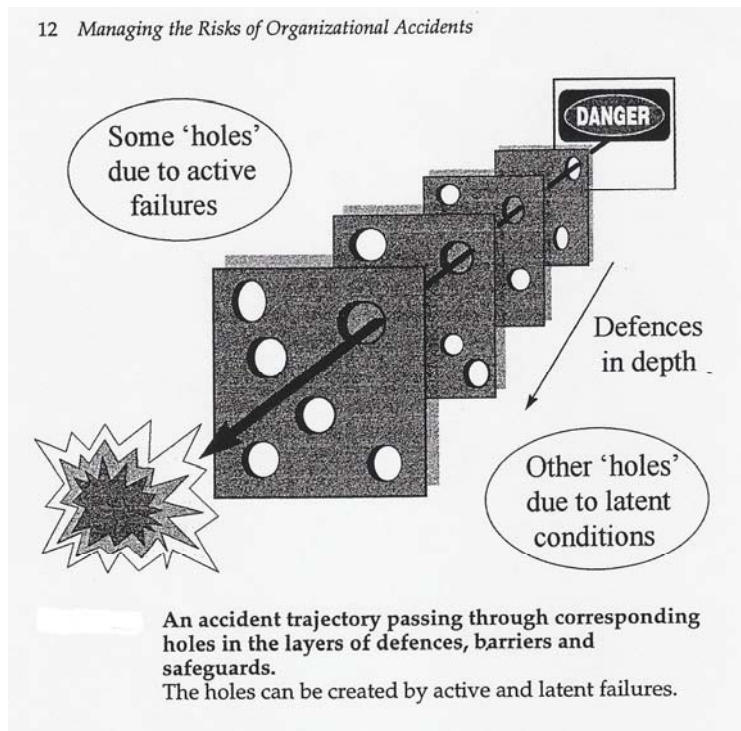


Figure 5: James Reason's Swiss Cheese causative model (1997)

This model represents all 'holes' or causes of equal importance and unlike legal and insurance processes, the front holes at the 'blunt' end (latent failures) are as significant as the holes closest to the accident or at the 'sharp' end (active failures). Under this model there is no single primary cause. The latent failures are as important as the active failures.

Recently Dekker (2002) proposed an alternative model of organisational accidents that is based on failure drift. Although he acknowledges with thanks the work of Reason, he criticises the Swiss Cheese model because it does not explain what the holes consist of or why they line up to let a failure become an accident (Dekker, 2002). He maintains that without the benefit of hindsight, error is hard to define and seeing the holes is difficult and therefore the Swiss Cheese model is not necessarily helpful in accident prevention (remember the Flight TE 901 pilots could not see that they could not see Mt Erebus). Therefore to try and understand why an accident occurs, it is necessary to reconstruct the unfolding mindset of the organisation and

individuals concerned *without the benefit of hindsight*. This is the perspective from which Dekker has developed his ‘Drift into Failure’ model and his new view of human error.

Dekker’s ‘Drift into Failure’ model consists of three points:

1. **People involved in accidents are not criminals or immoral deviants:** “Failure drift and accidents that follow them are associated with normal people doing normal work in normal organizations” (Dekker, 2005, p. 24)
2. **Often work involves deciding between conflicting goals:** Organisations that involve critical safety work are essentially trying to reconcile irreconcilable goals (staying safe and staying in business) (Dekker, 2005)
3. **Drifting into failure is incremental.** “Accidents don’t happen suddenly, nor are they preceded by monumentally bad decisions or bizarrely huge steps away from the ruling norm” (Dekker, 2005, p. 24).

Under this model “the potential of having an accident grows as a normal by-product of resource scarcity and competition” (Dekker, 2005, p. 24).

Dekker proposes a radical new view which he contrasts with the old as tabled below:

The Old View	The New View
Human error is a cause of accidents	Human error is a symptom of trouble deeper inside a system.
To explain failure, investigations must seek failure	To explain failure, do not try to find where people went wrong.
They must find people’s inaccurate assessments, wrong decisions and bad judgements	Instead, investigate how people’s assessments and actions would have made sense at the time, given the circumstances that surrounded them.
Murphy’s Law: Whatever can go wrong will.	Murphy’s law is wrong: What can go wrong usually goes right, but then we draw the wrong conclusion.

Table 1: Dekker’s old and new views of Human Error

With the benefit of Reason's and Dekker's models, it is helpful to review the investigative work of Mahon and Vette. Mahon's ten factors fits Reason's Swiss Cheese model well and the poor communication that existed within Air New Zealand between management and pilots was a significant latent failure at the blunt end of the accident timeline. Although Vette and Mahon painstakingly reconstructed the unfolding mindset of the pilots and determined clearly how the pilot's decisions made sense to them at the time, it was not possible to conduct a similar assessment with Air New Zealand management, who in a blameful context could have been defending their livelihood and the company's right to an insurance payout.

Had Mahon been able to achieve this he might have uncovered industry related problems, such as the poor communication that often exists between many captains and their co-pilots and the fact that civilian trainee pilots do not need to demonstrate comprehensively their skills in bad weather flying. Moreover, he may have discovered that previous whiteout air accidents had occurred before Erebus and that the reports of these accidents were not easy to obtain, as is the case for many air accident reports, even now. In the context of Dekker's new view of human error, the answers to questions such as these may have provided credible reasons for the actions of Air New Zealand management and shown them in a more reputable light than even the Court of Appeal and the Privy Council were able to. At least the Erebus accident organisational accident was investigated comprehensively. Many, such as the Leaky Building Syndrome, are not.

The Leaky Building Syndrome (LBS)

The Leaky Building Syndrome (LBS) arose in the late 90s after the requirement to treat framing timber with Boron biocide was relaxed. LBS is caused by the ingress of moisture through a building's external membrane and into its timber framing to the extent that favours fungal activity which in turn leads to decay of the timber and health risks for the building users. The final cost to the industry is difficult to estimate but has been estimated by some to be in the order of several billion dollars.

Contrary to common knowledge, this is not the first time that the country has experienced 'leaky building' problems. There is a concern that this problem has not been properly investigated and the controls that have been put in place may not be

necessarily appropriate or effective and another 'Leaky Building' type of problem could recur in the future.

LBS is not just caused by the relaxation of timber treatment alone. It is contributed to by the absence of eaves, cracking of plaster clad houses at the joints and walls that incorporated no free drainage cavity between the cladding and the supporting framework. This is shown schematically in Figure 6 below.

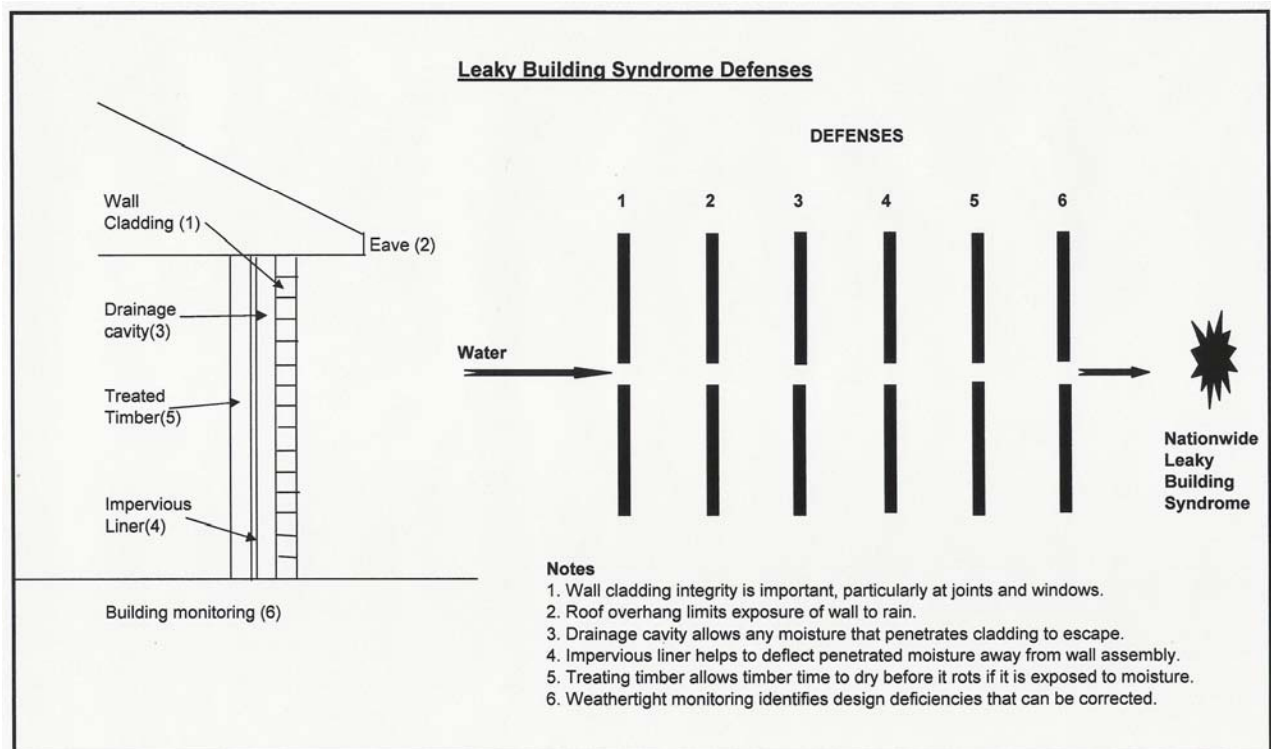


Figure 6: Leaky building defences

In order to understand how and why New Zealand became exposed to LBS after 1996, it is helpful to examine a brief history of LBS in New Zealand over the last century.

History

Around the turn of the 19th century, villas were built relatively high off the ground. During the 1920s, they were lowered to suit the Californian bungalow appearance but unfortunately to the extent that under floor ventilation was compromised. This increased the moisture content in the sub floor space which in turn led to borer decay and wood rot. The problem was solved by improving under floor ventilation and

ensuring that sub floor timbers were durable. However a large number of homes had already deteriorated extensively and the government took ownership of these homes during the depression.

During the 1920s-1930s, the supply of native timbers began to deplete, forcing the building industry to consider the use of inferior timbers such as Radiata Pine.

In 1939, various parties with an interest in building including the State Advances Corporation, commissioned the Department of Scientific and Industrial Research (DSIR) to investigate various options for the treatment of Radiata Pine against both wood rot and insect attack. Radiata timber framing began to be treated with Boron during the 1950s.

After the war and during the 1950s, stucco plaster claddings became relatively popular in the context of material shortages, limited choice and the Art Deco style which came into vogue after the 1931 Napier earthquake. However many houses with these claddings leaked at cladding joints and those without eaves leaked the most. Because of the poor weather-tight performance of plaster claddings, architecture trends changed to brick and tile buildings, which were comparatively more weather-tight due to the relatively wide eaves and the clear drainage space between the brick and the structural frame.

In 1957, a QUANGO called the Timber Preservation Authority (TPA) was formed to regulate and control the treatment of timber. During the mid 1980s, the TPA approved an alternative form of timber preservative for decking that was based on ammonia. This failed and resulted in hundreds of rotting decks which attracted compensation claims that the government paid out. In the context of increasing deregulation the TPA was disbanded in 1987 limiting any future government liability. However Industry recognized the need for some form of body such as the TPA and replaced it with a voluntary body called the Timber Preservation Council (TPC) which was an advisory body only that lacked the teeth of the TPA.

During the oil crisis of the 70s, building insulation was inserted into the walls of buildings to conserve energy. However this reduced the drainage and ventilation effectiveness of the wall cavity. The need for wall ventilation was removed from NZS 3602 in 1990 but the requirement for sub floor ventilation remained.

During the mid 80s in a political context of increasing deregulation, funding to the NZ Standards Association was significantly reduced. To this day company representatives and consultants contribute to the formulation of new standards on a voluntary basis, without even their disbursements being reimbursed.

At a similar time, several New Zealand commercial buildings suffered weathertightness problems around Aluminium curtain wall joinery. In response to this, the window framing industry and the Australian equivalent of the DSIR, CSIRO developed the Sirowet test (Australian Standard AS 4284).

Also during the mid to late 1980s, polystyrene based claddings were introduced followed by the re-introduction of stucco and the development of fibre cement options.

In 1990, the Building Industry Commission (BIC), reporting to the Department of Internal Affairs published a report titled “Reform of Building Controls” which “recommended the introduction of a performance-oriented scheme to replace the existing regulatory scheme which the Commission saw as overly prescriptive and stifling of innovation” (*Sacramento*, 2005, para. 7). The report believed that “a combination of light-handed regulation and the mechanisms of the market would produce better outcomes than the existing scheme” (*Sacramento*, 2005, para. 7) A new Building Act was commissioned in 1991 and this was largely an implementation of the 1990 BIC report. The Building Industry Authority (BIA) was set up to monitor the building control system established by the 1991 Act, with involvement in promulgating the building code, accrediting building products and processes and approving building certifiers.

During the early 90's, higher quality internal finishes were sought which required the kiln drying of timber framing to reduce timber moisture from a maximum of 24% down to 16%. Unfortunately kiln drying results in the evaporation of Boron chemical thus increasing the cost of boron treatment. This was the main reason why Boron treatment was reduced in 1993 and at the end of 1995 effectively eliminated. Moreover, with such a low moisture content made possible with kiln drying, the risk due to borer attack and wood rot was considered negligible.

In August 1995, NZS 3602 (1995) was revised and one of its changes permitted the deletion of timber treatment provided the moisture content could be maintained to 18% or lower. Interestingly, around this time the New Zealand Standards Association introduced a new standard titled AS/NZS 4360:(1995) Risk Management, which referred to several risk monitoring provisions as shown in Figure 7 below.

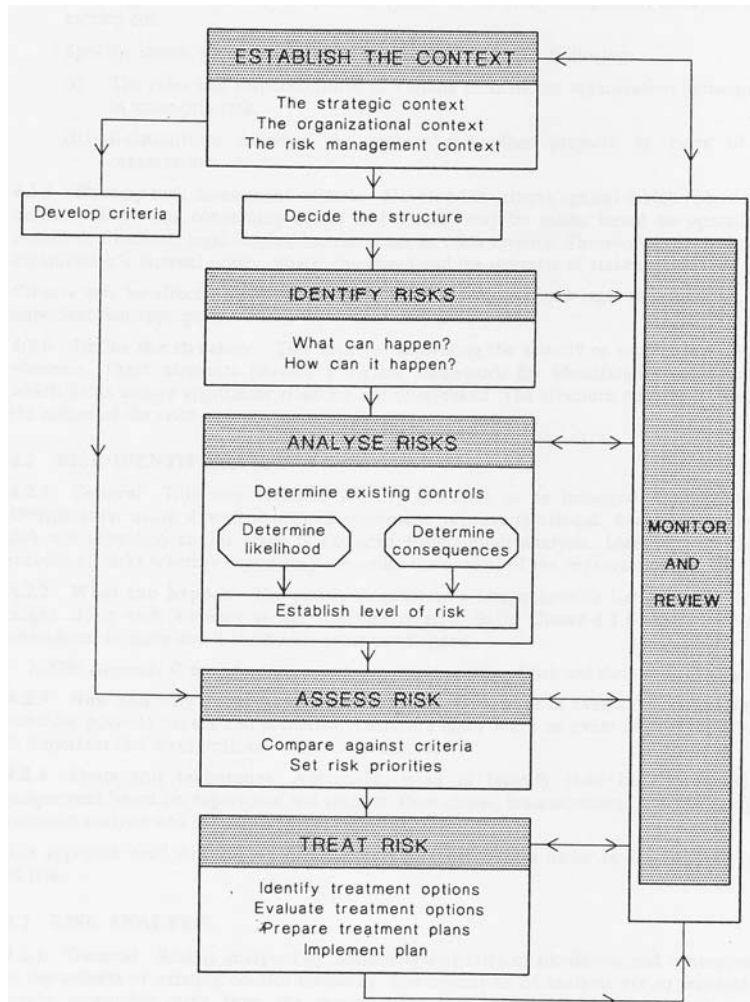


Figure 7: The Risk Management Process of AS/NZS4360:1995

For unknown reasons, the New Zealand Standards Association did not appear to incorporate the provisions of AS/NZS 4360 when deleting the requirement to treat timber framing with Boron. Had the process laid out in AS/NZS 4360 been implemented after Boron treatment was deleted, much of the widespread damage resulting from the 'Leaky Building Syndrome' could have been prevented.

One example of a large apartment complex that has suffered from LBS is the Sacramento Apartment complex in the suburb of Botany, Auckland. At the time of writing the Sacramento Body Corporate was seeking damages from a large number of defendants including the BIA. In December 2005, the Court of Appeal (CA) struck out the ability for the body corporate of the Sacramento apartment complex to sue the BIA for damages caused by the LBS. Even though the CA conceded several shortcomings of the BIA, it held that the BIA did not have a duty of care to the body corporate holders because of the BIA's lack of legal proximity to the body corporate members. Moreover, its resources allowed under the 1991 Act would not have been sufficient to undertake the extensive monitoring needed to prevent LBS. Also, because the BIA is a quasi-judicial body, it is protected by judicial immunity.

Regrettably, an effective risk managing strategy which the Standards Association itself promulgated in the form of AS/NZS 4360:1995 does not appear to have been implemented. The relaxation of Boron treatment was allowed without a compensating increase in monitoring and inspection requirements and without the Institutional memory of the Leaky Building lessons learnt during the last century.

Without comprehensively analysing the latent causes of the Leaky Building Syndrome, a collection of new legal controls have been implemented supposedly to prevent a recurrence. The implementation of these new laws perhaps shields the establishment from blame because it suggests that the cause was due to the negligence of industry practitioners, not defective design standards and controls which the industry looks to for guidance and which the BIA could have supplied, had the government provided it resources to do so. However this new web of laws may unnecessarily complicate future building processes and increase the cost of new buildings, which both the IPENZ book on Risk (IPENZ, 1983) and the 1991 Building Act tried to minimise. The new web of laws may also make it more difficult to attribute the cause of industry problems to defective standards or industry engineering controls in the future if warranted, and therefore the risk of problems such as the 'Leaky Building Syndrome' could recur.

Although it has not been possible in this paper to analyse the Leaky Building Syndrome comprehensively, this discussion at least summarises the areas of interest that a full investigation might address. Of particular concern is that NZS 3602 relaxed

the requirement to treat framing timber without the monitoring provisions of the Risk Management Standard, AS/NZS 4360.

Conclusion

The Erebus crash has shown the difficulties faced in investigating large organisational accidents and reflected the paradigm shift in thinking from an individual causation model to a more holistic and organisational view, a shift which the world is still learning about. It provided an example of how multiple causes can conspire to generate an accident with contributing factors totally invisible to the participants at the time. It fits both Reason's Swiss Cheese and Dekker's Failure Drift models.

Although the discussion on the Leaky Building Syndrome is not a comprehensive analysis on the leaky building problem, it nonetheless raises questions about the formulation and ongoing maintenance of standards in general.

After a brief introduction to the modern causative theories developed by Reason and Dekker which Erebus contributed to, it has been possible to link the organisational and human factors of the Erebus crash with the Leaky Building Syndrome. The comparison in the Table (Appendix 1), on page 19 shows how these simple models can be used to understand the cause of two completely different types of organisational accidents in totally different industries.

This study has shown the limited effectiveness of legal processes to determine the latent causes of organisational accidents, and the risk of future recurrences if their causal factors are not comprehensively determined and understood.

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References

Australian/New Zealand Standard. (1995). *AS/NZS 4360:1995: Risk management*.

Wellington: NZSA.

Beck, A. (1987). Trial of a High Court Judge for defamation?: A comment on the proceedings arising out of the Erebus Commission. *The Law Quarterly Review*, 103.

Dekker, S. (2002). *The field guide to human error investigations*. Hampshire: Ashgate.

Dekker, S. (2005). *Ten questions about human error: A new view of human factors and system safety*. London: Lawrence Erlbaum Associates.

IPENZ. (1983). *Engineering Risk*. Wellington: IPENZ.

Macfarlane, S. (1991). *The Erebus papers*. Auckland: Avon Press.

Mahon, P. (1981). *Report of the Royal Commission to inquire into the Crash on Mt Erebus, Antarctica of a DC10 Aircraft operated by Air New Zealand Limited 1981*. Wellington: PD Hasselberg.

New Zealand Standards Association. (1995). *NZS 3602: Timber and wood-based products for use in building*. Wellington: NZSA.

Reason, J. (1990). *Human error*. New York: Cambridge University Press.

Sacramento, Court of Appeal (2005).

The Transport Accident Investigation Commission Act 1990. (pp. 3-7).

Vette, G., & Macdonald, J. (1999). *Impact Erebus two*. Auckland: Aviation Consultants.

Appendix 1

Organisational Accidents: Some Common factors linking the Erebus crash and the Leaky Building Syndrome (LBS)

Item No	Human Factor/ Failure Model	Erebus Crash	Leaky Building Syndrome (LBS)
1	Latent Failures	<ul style="list-style-type: none"> ▪ Failure to identify risks of sector whiteout to pilots. ▪ Poor communication between company divisions and/or lack of procedures. ▪ No topographical maps issued to pilots. 	<ul style="list-style-type: none"> ▪ Failure to identify and monitor weathertight risks (ref AS/NZS 4360) ▪ Government deregulation ▪ No regulatory links between weathertight elements.
2	Active Failures	<ul style="list-style-type: none"> ▪ Failure to see mountain in clear air due to sector whiteout 	<ul style="list-style-type: none"> ▪ Cladding failures, particularly at joints and window junctions.
3	Conflicting Goals (Sydney Dekker) (Latent)	<ul style="list-style-type: none"> ▪ Safety v commercial sightseeing interests. 	<ul style="list-style-type: none"> ▪ The need for conservative controls to ensure weather tightness v the flexibility for industry to source and implement new technology freely. ▪ Wall insulation conserves energy but reduces drainage and drying effectiveness
4	Swiss Cheese Theory (James Reason)	<p>Some of Mahon's 10 factors:</p> <ul style="list-style-type: none"> ▪ The captain relied totally on the accuracy of the aircraft's navigation system which had been proven on countless occasions. ▪ The last leg of the track was altered prior to the flight without telling the flight crew. ▪ No topographical maps were supplied to the aircrew. ▪ Sector whiteout obscured Mt Erebus to the flight crew in otherwise good visibility. 	<p>Causal factors:</p> <ul style="list-style-type: none"> ▪ No eaves ▪ No wall drainage cavity ▪ No timber biocide ▪ Cladding cracking ▪ Failure to relax NZS 3602 in accordance with NZS 4360 ▪ NZS 3602 criteria for relaxing Boron difficult to measure continuously <p>Several of these had to occur together on a wide scale to cause LBS.</p>

Item No	Human Factor/ Failure Model	Erebus Crash	Leaky Building Syndrome (LBS)
5	Failure Drift (Sydney Dekker)	<ul style="list-style-type: none"> ▪ All individual participants were competent professionals and Air New Zealand had a good reputation. ▪ The latent failures had existed for many years without any formal awareness that they were systemic deficiencies. ▪ Due to the past success of these sightseeing flights Air New Zealand dispensed with the requirement to have two captains who had previously flown in the Antarctic on all Antarctic flights. 	<ul style="list-style-type: none"> ▪ Plaster clad and EIFS walls had been installed for several years prior to the NZS 3602 boron relaxation without serious weathertight problems. ▪ Boron treatment had been progressively reduced in 1974 and in 1993 without any serious weathertightness problems. ▪ The reduction of timber framing moisture from 24% to 16% achieved with kiln drying was seen by some as an improvement in building quality effectively masking more serious and latent weather tightness risks. ▪ Insulation was inserted into walls of houses during the oil crisis of the 70s, reducing the effectiveness of the drainage and ventilation effectiveness of the wall cavity.
6	Poor Institutional Memory (Latent) ¹	<ul style="list-style-type: none"> ▪ Other whiteout air accidents had previously occurred but this was probably not known to the Erebus pilots and they wouldn't have been able to research them easily had they been interested in doing so ▪ Appendix 13 of ICAO does not require accident reports to search for possible trends and does not require a literature search for similar accident reports. There is no worldwide database that 	<ul style="list-style-type: none"> ▪ Lessons from past LBS problems appear to have been forgotten.

¹ **Institutional Memory:** refers to the ability of an organisation to remember lessons learnt in the past.

Item No	Human Factor/ Failure Model	Erebus Crash	Leaky Building Syndrome (LBS)
		catalogues accidents in an orderly framework that can be conveniently accessed by operational staff.	
7	Confirmation Bias ²	<ul style="list-style-type: none"> ▪ Those on the flight deck interpreted features of the topography ahead in such a way as to confirm their mindset, not challenge it. The flat slopes of Ross Island and Beaufort Island were misinterpreted as features associated with McMurdo Sound instead of Lewis Bay at the foot of Erebus. 	<ul style="list-style-type: none"> ▪ Achieving low moisture content in timber framing through kiln drying appeared to confirm that the last defence against weather tightness, i.e. Boron treatment of timber framing was unnecessary.
8	Investigative difficulties	<ul style="list-style-type: none"> ▪ Blame issues. Blame in Mahon's brief was not consistent with International Accident Investigation procedures at the time. ▪ Privy Council and Court of Appeal overturned some of Mahon's findings, or were at least perceived to do so even though the international aviation community later accepted Mahon and Vette's findings. ▪ Both government and judiciary had at least an arguable conflict of interest in overseeing the investigative process. 	<ul style="list-style-type: none"> ▪ Hunn's report only discussed the extent of the problem, not the cause. ▪ The Latent causes of LBS have not yet been investigated. ▪ Both government and the judiciary have a conflict of interest in leading an investigation if there is a possibility of implication. Mahon's treatment after the Erebus inquiry would make it risky for an independent individual to formally and comprehensively determine the causal factors of LBS.

² **Confirmation Bias:** Confirmation Bias refers to safety checks and rhetorical questions which are supposed to challenge a mindset, but instead confirm it.

Item No	Human Factor/ Failure Model	Erebus Crash	Leaky Building Syndrome (LBS)
9	Unanswered questions	<ul style="list-style-type: none"> ▪ Why were pilots not trained in the hazards of sector whiteout conditions? Why don't trainee civilian pilots receive practical bad weather training given that bad weather crashes remain a common cause of air accidents? ▪ Why was the need to blame included in Mahon's brief when it was understood at the time that blame detracted from effective air accident Investigation? ▪ Why is there still no information database that allows operational users to conveniently refer to lessons from past accidents? 	<ul style="list-style-type: none"> ▪ Why did the industry not retain the LBS lessons learnt earlier in NZ's history? ▪ To what extent did the deregulation of the mid 1980's contribute to LBS? ▪ Was AS/NZS 4360: Risk Management referenced? If not why not? ▪ What other Latent systemic issues exist in other regulatory standards. ▪ How can LBS be investigated objectively and comprehensively without blame?