Analysing the Ansett Dash 8 Accident with a WB Graph

Why-Because Analysis

The basis for the system of analysis that we are about to look at is Lewis's Counterfactual Argument. You can see why Professor Ladkin called it 'Why-Because Analysis'! He first applied this method to check the validity of the report on the American Airlines accident near Cali, Colombia (ACRC, 1996), and it has subsequently been tested on a number of other accidents. It has the advantage over other methods, that it can be subject to formal validation. There is no reason why it should not be used during an investigation. Doing so might improve both the logic of the report, and the persuasiveness of recommendations. It can also provide a quality control check.

In general, where a system failure is one of behaviour, rather than 'something broke', and where there are interactions between machine, humans and the environment, it may be unclear where faults can be traced. Aircraft accidents involve such interactions. They are among the most meticulously researched of industrial accidents, yet the final reports on them are often inadequate. As Ladkin says, once all salient events and contributing system states have been discovered, there remains the task of analysing causality. It is mostly in this area that deficiencies are found.

Why-Because Analysis extends techniques that were originally developed to specify what is expected of a digital system, to the causal analysis of systems. It is intended to handle the failure analysis of complex, open, heterogeneous systems. 'Open', in this context, means that the system is highly affected by its environment, and 'heterogeneous' means that the system has components of different types that are all supposed to work together. An aircraft is such a system.

Ladkin reviewed a number of reports of high-profile aircraft accidents, and found logical deficiencies in them. For example, the report of the accident to the Boeing 757 near Cali discussed some 60 important events or states, but the findings mentioned only a quarter of them. One finding directly contradicted a causal factor mentioned in the body of the report. One reason for mistaken logic in reports could be that an accident explanation often forms a complex structure: the causal states or events in the Cali report have 73 direct causal connections between them (Gerdsmeier, 1997). Why-Because Analysis allows objective evaluation of events and states as causal factors.

The first step in the analysis is to develop a Why-Because Graph of the failure scenario, showing a complete statement of the causal relations between all the elements and system states which explain the failure scenario. The graph is similar in concept to Benner's Multilinear Event Sequencing flowchart (Benner, 1994), the principal difference being that it includes states as well as events. (An 'event' is 'something that happens', such as an action by the pilot; a 'state' is a 'continuing state of affairs', such as the existence of a hill (Bennett, 1988)). The Why-Because Graph is based on a formal semantics of causality introduced by Lewis, known as counterfactual argument (Lewis, 1973); (Lewis, 1986). "If A is a causal factor of B, then in the nearest possible world in which A did not happen, neither did B" (Ladkin 1999, p. 9). Consider the A 310 over-run at Warsaw:

> *The aircraft overran the end of the runway and struck an earth embankment beyond the runway end. The accident investigators described the sequence of events, but did not consider the embankment to be in any way causal, and made no recommendations about it. Yet, as Ladkin points out, had the embankment not been there, the damage and loss of life would not have occurred (a counterfactual argument). The presence of the embankment was a necessary condition for the disaster that ensued; its removal would certainly avert a repetition, so this would seem to be a proper matter for a safety recommendation. How did the investigators come to overlook matters which, thus stated, seem self-evident?*

In the usual case, where many causal factors come together to make something happen, we ask a question of two events or states at a time, and so on pair by pair until all possibilities are covered.

The second step is verification. To ensure that the Why-Because Graph correctly represents the causal relations, and that enough factors have been identified to provide a sufficient causal explanation, a formal proof is required. The method of formal proof, Why-Because Analysis, is based on a technique used in the specification and verification of digital systems, and is detailed in a paper entitled 'Why-Because Analysis: formal reasoning about incidents' (Ladkin, 1998).

It is not unusual for an accident investigation to be incomplete, in that the investigators are unable to find evidence relating to some state or event of which they are aware that their knowledge is inadequate. Why-Because Analysis deals with the situation where there is simply insufficient evidence to formulate a unique description, by providing an alternative description, representing the alternative possibilities as a 'Predicate-Action Diagram'. This enables the area of uncertainty to be defined, so that corrective actions can still be devised. The Predicate-Action Diagram is explained in (Ladkin, 1998).

However, a more difficult situation arises in the case where the investigators don't know that they don't know something. These are called 'unknown unknowns' - things the investigators have not even imagined. . A good example of such unknowns is the cabin pressurisation fatigue which brought about the Comet disasters (RAE, 1954). Possibly, if the investigators were aware of the deficiency, a further search might find the necessary evidence. Why-Because Analysis applies a variant of Mill's Method of Difference (Mill, 1873):

> *To find a causal explanation of a significant fact, ask how the system behaviour would have been different had that fact not pertained, Compare the behaviour with and without that fact. The first significant place that those behaviours diverge contains a causal factor: try to identify it, and repeat the process with the new factor.*

Consider, for example, the series of accidents to Pterodactyl microlight aircraft, involving in-flight break up. These were postulated to have occurred through static overload, from a variety of causes: overstressing by an inexperienced pilot, gust loads from turbulence near trees, drag or bending forces arising from excessive speed, and so on. In the wreckage from one accident, it was found that a bracing wire was strained almost to breaking point, in one part of the wire only. Since we know that static loads throughout a wire are uniform, we can eliminate from consideration all the factors which might have caused a static overload. All that is left is dynamic (i.e. oscillatory) loading - flutter. Other evidence was sought, and it was shown that torsional flutter of the wing was the damage mechanism. The structural damage in all cases was identical, so flutter was the immediate cause in all of them. We could now seek the reason for the flutter, and perhaps deal with it (TAIC, 1992).

This sounds obvious when put like this, but it was far from obvious at the time.

Ladkin observes that this is just an explicit formulation of good investigation practice, but has the advantage that what is explicit is also methodical. That which is methodical can be taught, and so the many can be brought up to the standard of the best (Zotov, 2000).

To deal with human actions, Ladkin uses an empirical taxonomy to describe the sequence of stages of situational response:

Perception - Attention - Reasoning - Decision - Intention - Action (PARDIA).

The similarity between PARDIA and the cognitive failure taxonomy developed by O'Hare et al. (O'Hare, 1994) is evident. On the basis that O'Hare's taxonomy has a sound theoretical basis and has been thoroughly tested (Wiegmann, 1997), (Zotov, 1997) it might be preferable to use it.

Finally, Why-Because Analysis is able to deal with the operating procedures and the regulatory framework in the same way as the behaviour of the physical or digital components of a system. Both the cognitive failure taxonomy and the procedures and regulations can be specified in the same formal language that the WBA proof system uses.

Ladkin has commented that the formal proof, and other steps such as devising a predicate-action diagram, are really matters for specialists in formal logic. This is not, of itself, any barrier to the use of Why-Because Analysis in investigation. Accident investigators are well used to consulting specialists in many fields [Zotov, 1999]. What is necessary is that they should understand the need for specialist input, and that they should understand what the specialists are telling them. However, it may well be that in the field stage of an investigation, Benner's simpler concept of Multilinear Event Sequencing (Benner, 1994) - forming mental movies, as Benner puts it - will be sufficient, and easier for investigators to apply.

A potential limitation of Why-Because Analysis in dealing with multiple causative factors lies in the area of the over-specified accident, such as that involving the Air Ontario F28 at Dryden (Moshansky, 1992).

> *A Fokker F28 operated by Air Ontario attempted to take off from Dryden, Ontario, in a snow- storm. It got airborne but failed to climb out of ground effect, and crashed into trees beyond the runway. The airframe and engines were serviceable, and the principal question for the investigators was, "Why would a captain with 24 000 hours flying experience attempt to take off with four inches of snow on the wings?"*
>
> *The human factors investigation disclosed some twenty factors tending to put the crew under pressure, and the conclusion was that the crew was under such pressure that they were incapable of making a rational decision not to take off. (Helmreich, 1990); (Moshansky, 1992).*

In effect, what happened here was that the load on the crew exceeded some threshold value beyond which their cognitive ability declined severely. There were more than sufficient factors to bring this about: the accident was over-specified. We cannot say that absent x, the accident would not have happened; absent x, y, and z it might still have been feasible, and alternatively the absence of a, b and c might not have averted the accident. Yet it would be incorrect to say that the factors identified by Helmreich were not causative: some or all of them needed to be present for the accident to occur.

A second difficulty appears to lie in the binary nature of the decision: would the event or state have occurred, absent the precursor? It may be that the real answer is that it is more likely to occur, if the precursor was present; also, it is possible that variation in the degree of the precursor would cause a subsequent factor to be present in greater or lesser degree. To take a simple example, excessive speed at touchdown will cause a longer than expected landing roll; still higher touchdown speed will cause the landing roll to be even longer, and may cause it to exceed some threshold value beyond which obstacles are encountered.

<u>The Ansett Dash 8 Accident</u>

The Why-Because Graph of the Dash 8 accident was prepared as part of the preliminary work in the action brought by the surviving passengers against the airline. Attention was focused on the underlying corporate actions which had resulted in the crew being put into a position to make unsafe actions (Reason, 1991).

The Why-Because graph of the Ansett Dash 8 accident shows two features which could be of value to investigators:

- It enables identification of what Dettmer calls 'core problems', that is, single features from which a significant number of subsequent factors stem (Dettmer, 1997). Eliminating these may not only avert future accidents from the same immediate causal factors, but also other, quite different potential accidents. They are similar to Reason's 'latent failures', but do not necessarily stem from management decisions.
- It enables the effects of management decisions to be linked to the accident, in a way which has proved somewhat elusive in the past.

In the morning of 9th June 1995, DHC-8 ZK-NEY operated by Ansett Airlines was on a non-precision instrument approach to Palmerston North aerodrome. The starboard main undercarriage leg stayed up when the undercarriage was selected down. The crew attempted to lower the leg using the emergency system, and while they were doing this the aircraft struck a hill. Of the 21 occupants, 4 were killed, and fourteen seriously injured. The Transport Accident Investigation Commission (TAIC) investigated the accident (TAIC, 1995). The Report identified the following causal factors:

- *The Captain not ensuring the aircraft intercepted and maintained the approach profile*
- *The Captain's perseverance with his decision to get the undercarriage lowered without discontinuing the instrument approach*
- *The Captain's distraction from the primary task of flying the aircraft safely during the First Officer's endeavours to correct an undercarriage malfunction*
- *The First Officer not executing the Quick Reference Handbook procedure in the correct sequence*
- *The shortness of the ground proximity waning system warning*

The prosecution rests its case, Your Honour.

We can construct a Why-Because Graph by starting from a significant event, and working forward or back in time. It is convenient to start with the initial impact with the hill, which happened at 09 22 30 local time. As originally devised by Ladkin, the graph had no timebase, but nothing is lost by incorporating one. With a timebase, there is likely to be more crossing of causal links, but this reflects reality: what (Helmreich, 1990) referred to as the complex network of interacting events. Events during the flight may be placed in exact time sequence, using information from the aircraft and ATC recordings. As we go back earlier in time, our knowledge of exact timing becomes less precise, but also less important. It may be found convenient to use a quasi-logarithmic format as suggested in (Zotov, 1996), where the timebase is divided into 'days before', 'months before' and 'years before' the accident. The graph, as presented now, has no explicit timebase, but events are arranged in chronological order.

So, let's start with the initial impact, and ask ourselves 'Why did the aircraft strike the hill?'

The first answer has to be 'Because the hill was there'. Never mind that many approaches are over hills, or whether the approach complied with PANSOPS criteria. Had the approach been from the opposite direction, the accident *would not have occurred*, because the approach to runway 07 at Palmerston North would have been over level terrain at the same height as the airfield, and the aerodrome level was below cloudbase (the counterfactual argument). The presence of the hill was therefore an essential causal factor. Likewise, the next answer is 'because the aircraft was in cloud'. Had the aircraft been in VMC, the accident would not have occurred, because the crew could have seen the proximity to the ground.

Clearly, the accident could not have occurred had the aircraft been stabilised on the proper glidepath, since this was clear of terrain. Continued descent below the glidepath was therefore a factor.

But there is yet another factor. The purpose of Ground Proximity Warning Systems (GPWS) is to alert the crew to the fact that they are getting too close to terrain. In the case of this accident, the warning time should have been 17 seconds, and this would have been more than sufficient for the crew to take avoiding action. Instead, they had only about 4 seconds, and this was insufficient (TAIC, 1995). So the inadequate GPWS warning (never mind why, for the moment) was a causal factor.

So far we have identified as causal factors the presence of terrain and cloud, descent below the glidepath, and inadequate GPWS. (See Figure 1).

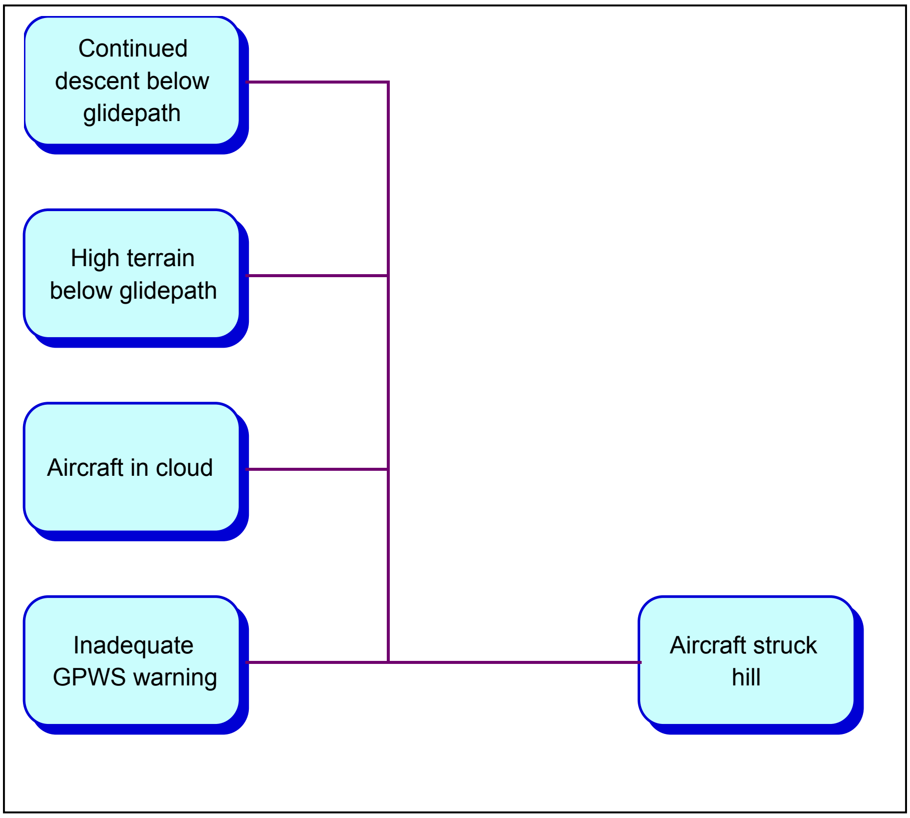


Figure 1. Why because graph construction: first step.

It may be that we could consider some of these factors as being things we take for granted.

Indeed, when we have completed the analysis, we might conclude that such conditions as descent over high ground, and descent in cloud, are such normal matters that they do not merit further consideration. However, they should be left in for the time being. It may be that we might consider that, although the approach safety margins met the ICAO PANSOPS criteria, the margins were inadequate for New Zealand conditions. And the fact that the aircraft was in cloud may be the answer to the question 'why did the accident not occur before?' There had been previous incidents of undercarriage malfunction which were sorted out by the crews, which did not result in accidents. However, as far as can be determined, all the previous incidents happened in VMC.

The next stage is to consider each of these factors in turn. Let us follow one particular line of reasoning: descent below the glidepath.

We would probably agree that a causal factor was that the Captain was not monitoring the approach effectively. *Why* his monitoring was ineffective comes later. But there is more to it than that. If he was not monitoring it at all, but the descent rate had been appropriate to maintain the glidepath, then the aircraft would have arrived at the aerodrome in good order. Inadequate monitoring is a *necessary* condition, but it is not *sufficient*. The aircraft was descending at a greater rate than that needed to maintain the glidepath. (Again, *why* it was descending at this rate will be considered later). But even this was insufficient, on its own, to cause the aircraft to strike the hill. Had the aircraft descended at the rate established by the speed and power setting, it might have cleared the hill. The crew might have been surprised to find the aircraft so low, but no accident would have ensued. As we can see from the official report (TAIC, 1995) (p. 28), the rate of descent increased by about 400 feet per minute, some 30 seconds before the accident, bringing the descent path below the height of the hill.

Why was the descent rate greater than that required to maintain the glidepath? The approach required a steep descent to reach the normal glidepath, after completion of the initial DME arc approach. Had the initial approach been completed at a height appropriate to the normal descent path, standard power settings would have resulted in a descent path closely approximating to that desired. However, the high initial descent rate in itself was insufficient to cause the accident: had the standard power setting been applied when the aircraft had descended to the normal glidepath, there would have been no problem. But, before the proper glidepath could be established, the crew were distracted by an undercarriage malfunction, and standard descent power was never applied.

So to recap thus far: The descent rate was excessive because the final approach was started above the normal level, the standard descent power settings were never applied because the crew was distracted. For the same reason the glidepath in the later stages was not monitored effectively. In the final stage of the descent the descent rate was increased (because a smooth downdraught was encountered (pp. 23, 76)) and the resulting glidepath intercepted the hill. (See Figure 2).

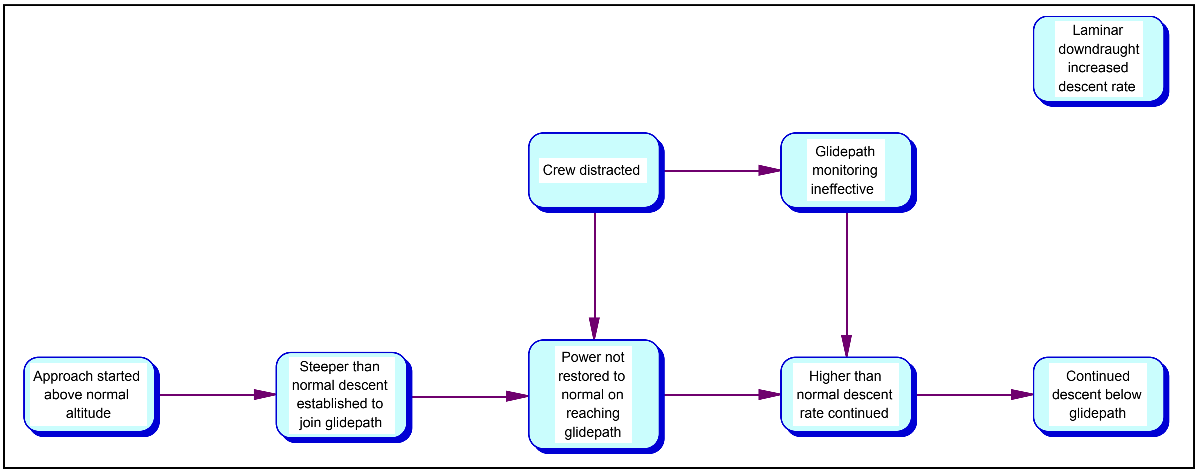


Figure 2 Why-Because Graph: second step.

Notice that we have used the abstraction

"The crew was distracted"

to cover two quite different things: the *event* of the undercarriage warning occurring just at the point at which normal descent power was about to be re-established, and the *condition* of continued distraction from monitoring the glidepath by the subsequent problems in rectifying the malfunction. There is too much information loss here. The initial distraction was unavoidable as far as the crew were concerned, whereas the second could have been avoided by choosing a different strategy, or by better Crew Resource Management (CRM). We therefore need to elaborate on this section, as shown in Figure 3.

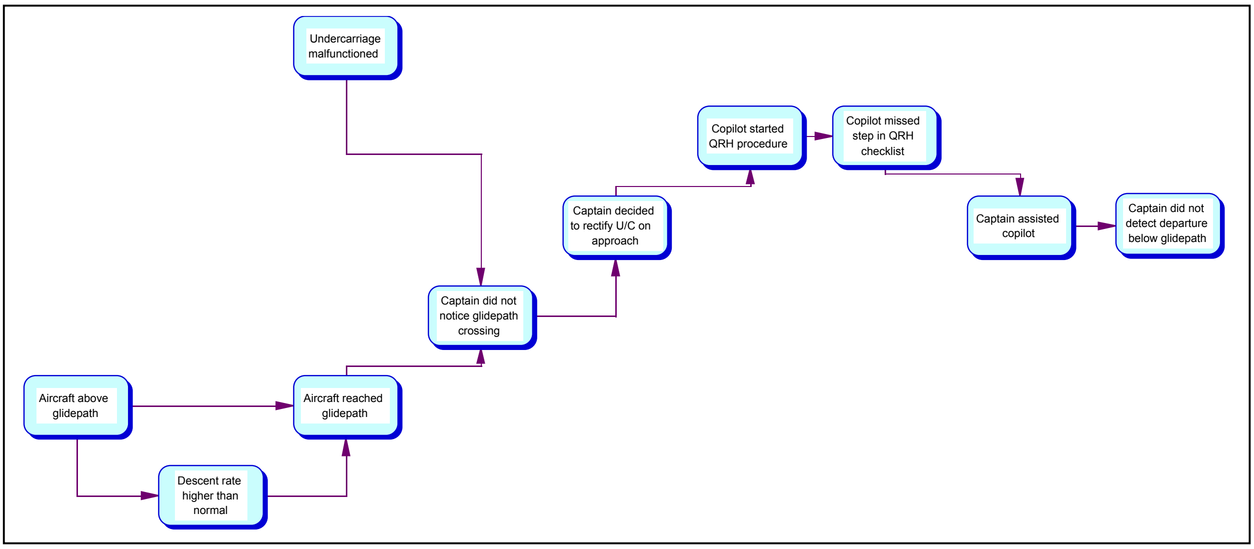


Figure 3. Elaboration of Fig. 2.

However, we can see that there are inadequacies here. 'Captain helped Copilot' seems a rather inadequate explanation for 'Captain did not detect departure below glidepath'. Were there other factors which might, singly or in combination, have contributed to this result? There are a number of potential factors which are alluded to in the report: Fatigue, inadequate CRM, and (possibly) misreading of the altimeter.

While the report acknowledges the loss of sleep occasioned by the early start of the duty day, fatigue is dismissed as a factor because the crew had had adequate sleep on the two previous nights. This implies that a sleep surplus can be 'banked' against a future deficit. I know of no evidence that this is the case. There is a lengthy list of slips, lapses, and mistakes (p. 61), but no alternative explanation is adduced as to why an experienced crew should have made such a catalogue of errors in a half-hour period. The co-pilot's comment (p. 114) "Oh gee, excuse me, I'm tired" would have been deathbed testimony had he not survived. Indicators of fatigue include consequences such as slowed reaction times, narrowing of attention, lack of alertness, poor monitoring.. There appears to be an arguable case that the crew were affected by fatigue, and that this was a factor in the captain's ineffective monitoring, and in the co-pilot's incorrect performance of the QRH checklist.

There is also evidence to suggest that the captain may have misread his altimeter (p. 48). While the drum and pointer display is less likely to be misread than the older three-pointer altimeter, it still requires a conscious effort to read the height. If the pilot looks away from it, and a short time later looks back and finds the pointer in an expected position indicating rather lower than before, it is feasible that he might not read the 'thousands of feet drum', and so not notice that the aircraft was a thousand feet lower than he thought. When he did subsequently read the drum, it is reasonable that he would attribute the discrepancy to a 'jump' in the altimeter reading.

There is no dispute that Ansett's CRM training was deficient, nor that proper application of CRM could have resulted in better monitoring of the flightpath by both pilots.

These matters need to be addressed in our graph.

In the same way, 'co-pilot performs QRH procedure' is a necessary factor in 'co-pilot misses a step in the check-list', but it could hardly be considered sufficient! Other factors must have been at work here. The report refers to defective design of the checklist, but this deficiency alone does not account for poor performance. Equally relevant is that the co-pilot had *never* practised the procedure, and probably had never been taught it. His training record shows that it was checked off, along with eleven other items, on a flight primarily devoted to asymmetric handling.

These matters, too, need to be incorporated.

And why did the captain choose the strategy of attempting to rectify the malfunction while continuing the approach? Not only was there no written SOP to the contrary, but company culture was that this should be done. Of at least seven other occurrences, on only one does the captain's post flight report state that the aircraft climbed away before the problem was rectified. Several reports expressly stated that the rectification was done while continuing the approach. We are not told in the report, but it is unlikely that crews generally were unaware that this was 'the way things are done around here'.

This part of our graph now looks as shown in Fig. 4.

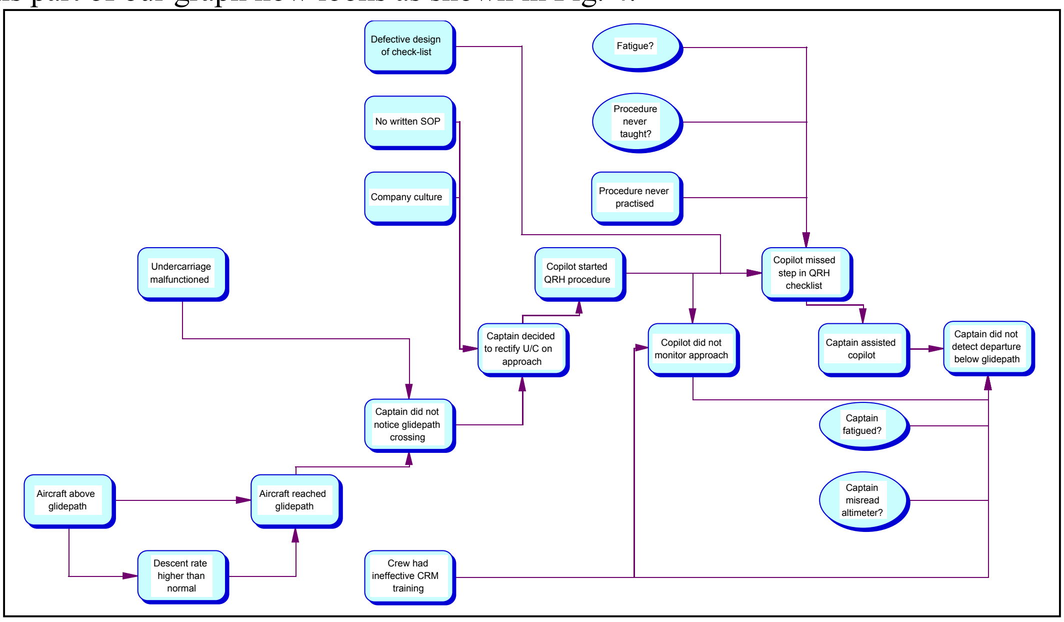


Figure 4. Development of Fig. 3

There are a number of loose ends in this section of the graph which we need to address next:

- Why was the aircraft initially high on the glidepath?
- Why was the co-pilot untrained in the emergency lowering procedure?
- Why was the CRM inadequate?
- Why did the undercarriage not lower when selected down?

We will cover each of these points with a separate diagram, which will subsequently be incorporated into the overall picture.

Why did the approach require an initial steep descent? The final part of the DME arc up to the lead radial had a minimum altitude of 4900 feet. Assuming the turn could be completed and the aircraft established inbound by 12 DME, where the glidepath altitude was 4030 feet, the aircraft needed to lose nearly 900 feet while making the turn (p. 30). The aircraft reached the lead radial at 4900 feet, and so was on profile at this point. However, during the turn the descent was stopped at 4700 feet, and the aircraft was some 500 feet high on completion of the turn (p. 28). Why did the pilot stop the descent, and so find himself above the glidepath? The reason appears in the CVR transcript at 09:11:42 (p. 116), where the crew are re-briefing themselves for the (unanticipated) approach to runway 25:

Captain Inbound twofifty down the approach not below forty six hundred to start off with and not below three thousand at nine miles…

This was incorrect. The 4600 feet altitude restriction applied to aircraft inbound from the Woodville holding pattern which was outside the DME arc. The restriction was inapplicable inside 14 DME, where the appropriate restriction was 3000 feet to 9 nm (p. 30). The Captain had only flown the approach once before (p. 111), and not as handling pilot (p. 64), so the confusion is understandable. According to the report, the copilot had 'flown the procedure several times before' (ibid.), but we are not advised as to whether he was handling the aircraft at the time. His comment (at p. 111) does not suggest familiarity with this approach. Accordingly, the answer to 'why was the aircraft high on the approach?' is 'because the pilots were unfamiliar with the approach'. This of itself is insufficient, of course: many pilots fly approaches with which they are unfamiliar, and manage to fly them accurately. So again we look for additional factors. We might consider the approach plate to be potentially confusing; certainly the pilots were confused. And fatigue might have been a factor here, as in the errors identified in the report.

And why were the pilots unfamiliar with the approach? In an airline, one would expect that pilots would receive recurrent training, either in a simulator or in the aircraft. The introduction of a new approach procedure to an aerodrome routinely used by the company would be a matter which would normally be addressed in such recurrent training. The nearest simulator was in Seattle, and Ansett advised the CAA that they would therefore train their crews in the aircraft rather than in a simulator. However, we know from Company memoranda that the company had difficulty making the two Dash 8 aircraft available for engineering, because the demand for line flying was high. This may explain why the crews training records showed no recurrent training in the aircraft. See Figure 5.

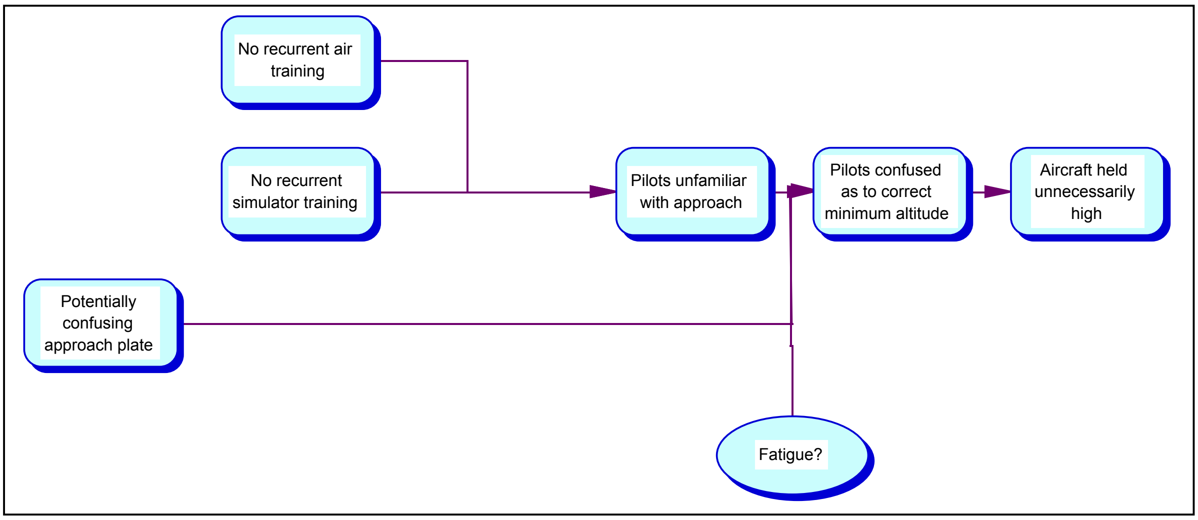


Figure 5. Attachment to Fig. 4.

There are two factors which led to the incorrect actions by the copilot:

- The unsatisfactory QRH had not been recognised as such. It could have been detected earlier if the exercise had been practised, in simulator sessions or even in a simplified Crew Procedure Trainer. The defective pages could then have been re-designed and re-issued.
- The specific emergency had never been practised as such, either in the aircraft or in a simulator. The nearest simulator was in Seattle, and the company decided as a matter of economics that training would be performed in the aircraft. However, emergencies are not permitted to be practised during revenue flights, and there was no evidence that aircraft had ever been made available for continuation training in emergencies. The copilot said that he had never operated the emergency undercarriage mechanism. His training record showed the procedure as having been signed off during a conversion training flight, six months before the accident, in which 11 procedures were signed off. This was a flight primarily devoted to asymmetric handling (Base training record dated 17 November 1994). (See Figure 6).

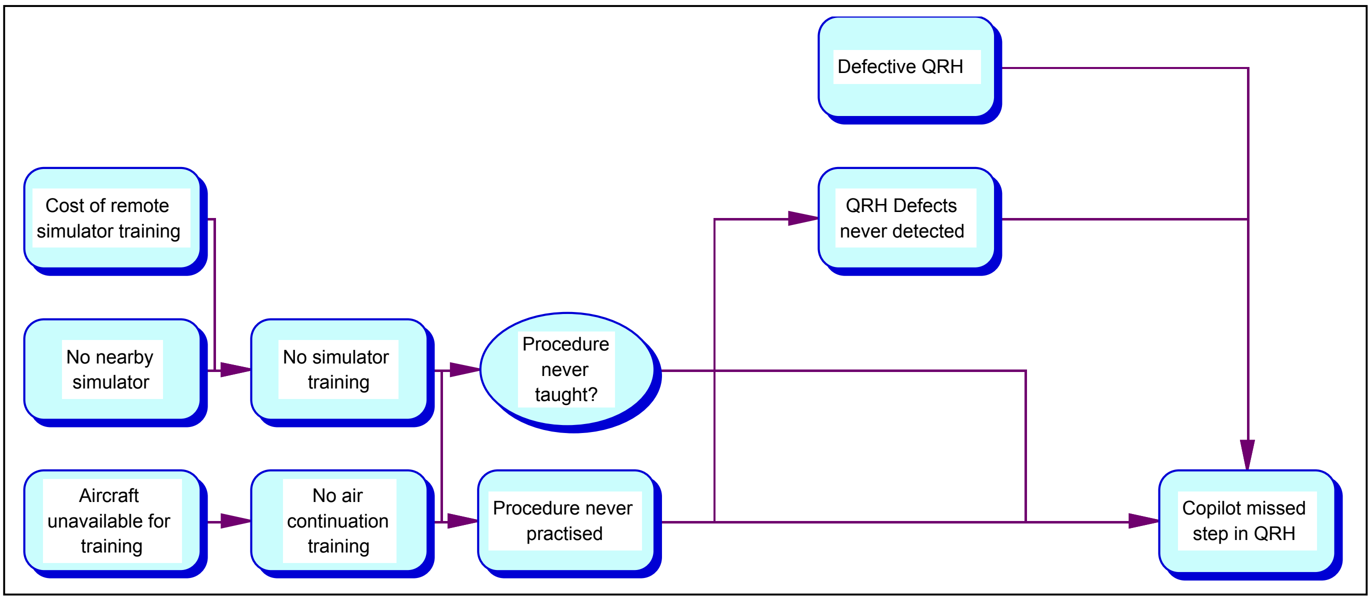


Figure 6. Attachment to Figure 4.

It is worth digressing, at this point, to consider the effect of missing out the step in the procedure, as the copilot was about to do. Opening the cover in the cabin ceiling, which gave access to the cable release, released pressure from the hydraulic system and removed the force which prevented the undercarriage up-lock from releasing. Pulling the cable then forced the up latch open, so the leg could free-fall down. Pumping the floor-mounted handle, as the copilot was about to do, then re-pressurised the system to ensure that the leg remained down under landing forces. This latter action was not reversible in the air. It thus appears that pumping up the pressure before the leg was lowered would have re-pressurised the system, locking one wheel up and the other two down. Again, we are not told, but if this was the captain's understanding, the co-pilot's actions would have grasped his attention.

It could also be argued that Crew Resource Management (CRM) should have averted the distraction before it became hazardous. The copilot made no attempt to monitor the height while he was trying to perform the QRH procedure, and the captain was unaware of the absence of height calls by the copilot. However, the crew's CRM training consisted of a few hours of lectures: absent a simulator, there was no possibility of Line Oriented Flight Training (LOFT), to provide practical reinforcement. Indeed, the captain's action in monitoring the actions of the copilot could be construed as good CRM. (Figure 7).

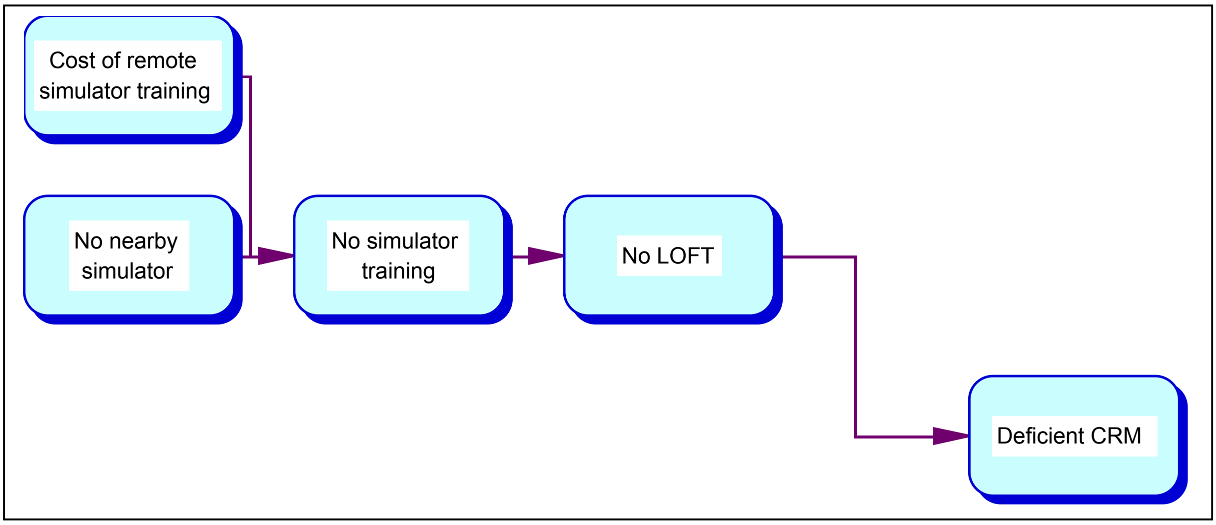


Figure 7. Attachment to Figure 4.

As you can see, a recurring theme is the absence of simulator training. A post-accident review by the parent company decided that not having simulator training was acceptable, provided that air training was provided instead. This might be questioned, in view of the now-accepted benefits of CRM and LOFT training. These benefits can only be fully realised with simulator training. Besides, the decision to use air training in place of simulator training implies a commitment to making airtime available for training. It appears that the co-pilot's training was skimped as far as emergency procedures were concerned, and there is no record of continuation training at all.

So far, we have concentrated on the crew's handling of an emergency. Next, we need to consider how the emergency came about: what was it that put the crew in the position to make the active failures that led to the accident?
The immediate emergency, of course, was that one undercarriage leg did not extend when the undercarriage was selected down. Unless corrective action was successful, the crew were faced with landing the aircraft on two wheels.

Why did the leg hang up? The mechanical cause was that the up-lock was worn to the extent that the aircraft hydraulic system could not generate insufficient force to dislodge the lock and allow the leg to descend. But how did the aircraft come to be flying with such a defective uplock? The engineering staff were aware of the possibility of wear, and the shop floor mechanics had been told to 'inspect for wear'. (TI 008-32-74, dated 27 November 1992). The mechanics interpreted this instruction to mean that they should 'rub a fingernail over it' (the surface of the latch), to detect wear. In fact, a smooth depression in the surface of the latch of a few thousandths of an inch depth was sufficient to cause a leg to hang up, but this advice was not passed on to the shop floor. Accordingly, the necessary and sufficient factors for a leg to hang up were wear on the latch, and the failure to detect such wear, which in turn arose from an inadequate instruction. The faulty instruction was a simple human error, made by a manager no doubt under significant pressure of work. But why had it not come to light before the accident, and why, in any event, was the wear occurring?

Let us deal with the wear first. The wear occurred because of inadequate design. The latch had been re-designed, and the manufacturer offered replacement units at a total cost of about $US20,000 for both aircraft. The company rejected this offer, on the ground of cost. No safety implications were considered: the crew could always lower the remaining leg with the alternate procedure.

The faulty inspection procedure could have been expected to become evident as soon as an undercarriage leg hung up, notwithstanding that the latch had been inspected. There were, in fact, a number of such 'precursor events' (Reason, 1990) before the accident: See Figure 8.

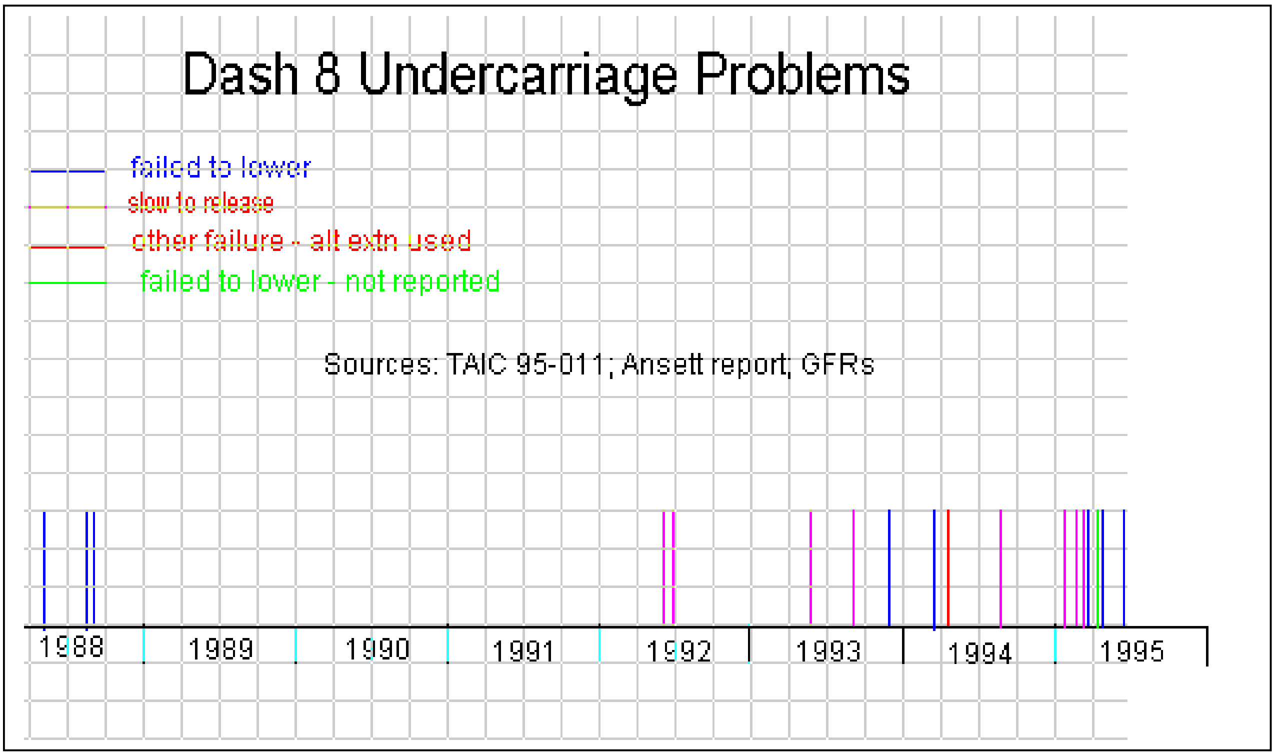


Figure 8. Precursor events

However, no one appears to have asked why these precursor events had occurred despite the inspections; all that happened was that 'corrective' action such as dressing the face of the latch was taken, and the aircraft was put back into service. It appears that no one at Ansett realised that the events were occurring at shorter and shorter time intervals, a sure sign of deterioration. One could reasonably say that the engineers did not know what they were doing, and that no one 'was minding the shop'. (See Fig. 9).

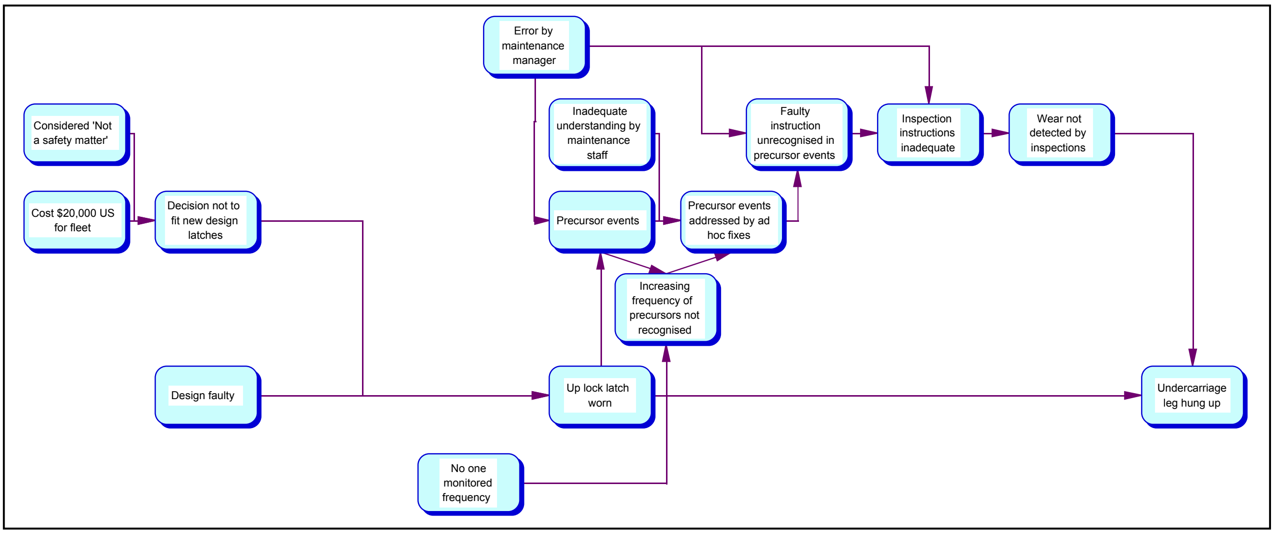


Figure 9. Engineering considerations.

So to recap, there was no guidance to the crew that they should climb out before attempting to correct the undercarriage malfunction. Notwithstanding that this malfunction was becoming an increasingly common occurrence, there was little or no briefing in undercarriage emergencies, and no training either in a simulator or in the aircraft. Nor had they had any worthwhile CRM or LOFT training. No one on the engineering staff seemed to realise that hang ups were occurring at shorter and shorter time intervals, nor that these stemmed from faulty engineering instructions.

The absence of simulator or flight training in an increasingly common emergency, and the inadequacy of CRM training, could be categorised as inadequate risk management. There was an unawareness in the company of the implications of undercarriage malfunction. Reports from the crews went to the operations manager, but appear to have occasioned no comment. The engineering department was concerned at the occurrences, but their concern was the loss of time, and the difficulty of keeping aircraft available for line flying commitments. A Company memorandum stated that the malfunctions were not a safety issue, because the crews could always lower the undercarriage using the emergency system. In short, there was nobody minding the shop. The department responsible for operational risk management in any airline is the Safety Department. But for a considerable time before the accident, Ansett had no safety department. The position of Safety Manager had been abolished, with the comment that 'safety is everybody's business'. It could fairly be said, that everybody's business became nobody's business.

How might having a safety manager might have averted the accident? Some matters would have been routine in a safety department. A recurring fault, which would have been reported to that department, would have been charted, and the increasing frequency would have been evident.

A recurring undercarriage malfunction would certainly not have been classed as having no safety implications. The safety department would have pressed for specific training in handling the emergency, either in a simulator or in the aircraft. Such training should have brought to light the unsatisfactory format of the QRH checklist. The absence of continuation training would have come to light, and it would probably have been possible to make a case for sending crews to Seattle for simulator training, given the high demand for the aircraft for line flying.

Reports of malfunctions being corrected while the aircraft continued on approach were certainly a matter likely to attract the attention of the safety manager, and the absence of an SOP requiring a climb to safe height before rectification would have come to light.

So, in answer to the question 'Why was there no risk management which could have averted this accident?' we may reasonably say 'Because there was no safety manager'. And why was there no safety manager? At this point, counsel for the passengers demanded production of the relevant Board minutes, but Ansett decided to settle out of court, so we shall never know. However, in view of Ansett's history of losses, year by year, saving the safety manager's salary may well have looked attractive. The absence of a safety manager is, as you can see, a core problem: many different factors stem from it. The absence of a safety department affects such a large range of factors that it is highly probable, had this accident not occurred, that some other accident would have arisen from factors within the province of the department. Identifying such a core problem should therefore enable a major safety improvement to be made.

Cost certainly affected other factors. The decision not to modify the undercarriage uplocks when modification kits were offered by the manufacturer, was to avoid the cost of about US$20,000 for both aircraft. This decision was made without any input as to the safety implications. Presumably, the decision not to send crews overseas for simulator training was also based on cost, and without regard to the safety issues. Thus, the financial ability of the airline to meet normal costs is also a core problem. In the past, an airline was required to demonstrate its financial viability. However, this requirement was done away with, in New Zealand, as a matter of Government policy. Perhaps it is time to revisit that policy?

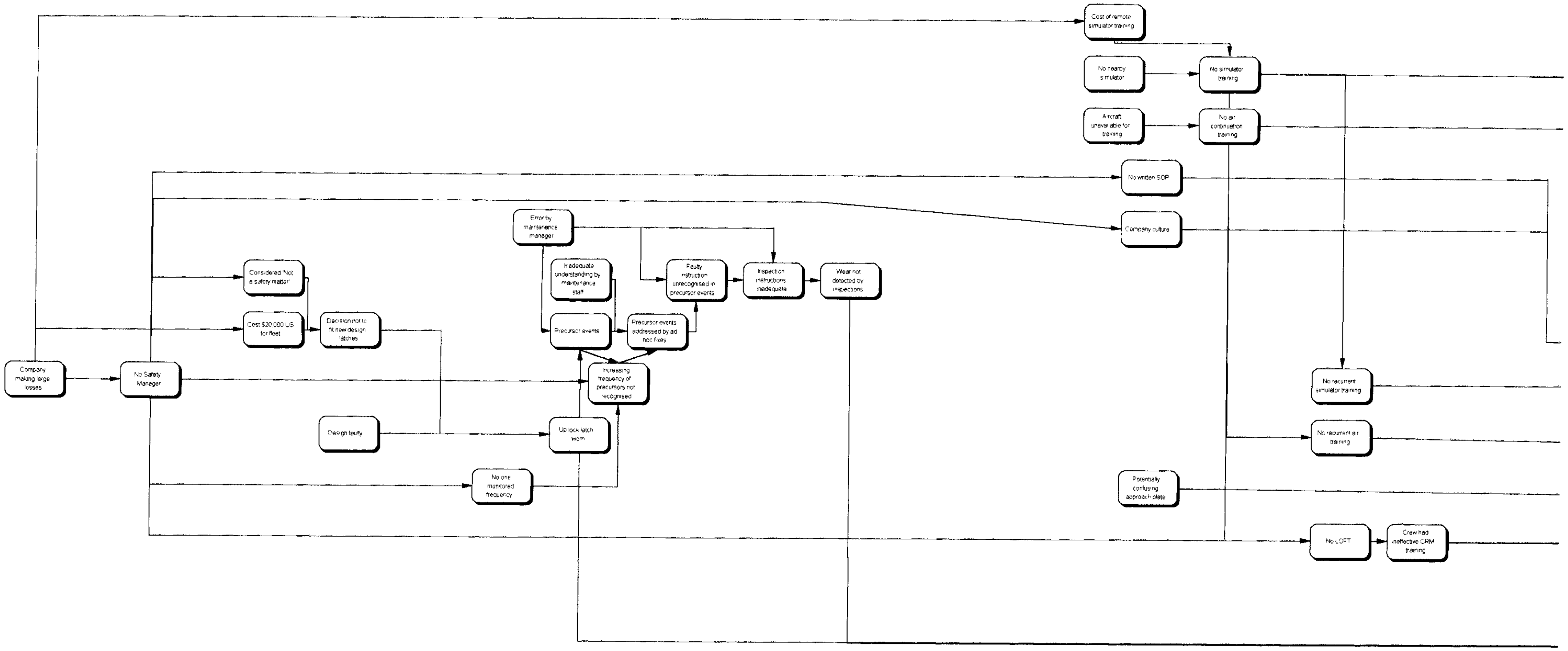
The overall layout of the Why-Because graph is shown on the next two pages.

Naturally, other factors figured in this accident. We have not considered other streams, and there are factors such as the defective GPWS that should be considered. The design of the approach to runway 25 at Palmerston North might merit further consideration. Nor have we addressed the question of why auditing by the Civil Aviation Authority (CAA) was ineffective. The answer to this latter question lies in Clausewitz's comment, that 'the map is not the terrain'. The CAA hadn't realised that there was no safety manager, because the manuals still said there was one. Inspecting the manual earned Ansett a big tick. Evidently, the CAA did not concern themselves with the various matters which would have been the province of the safety department.

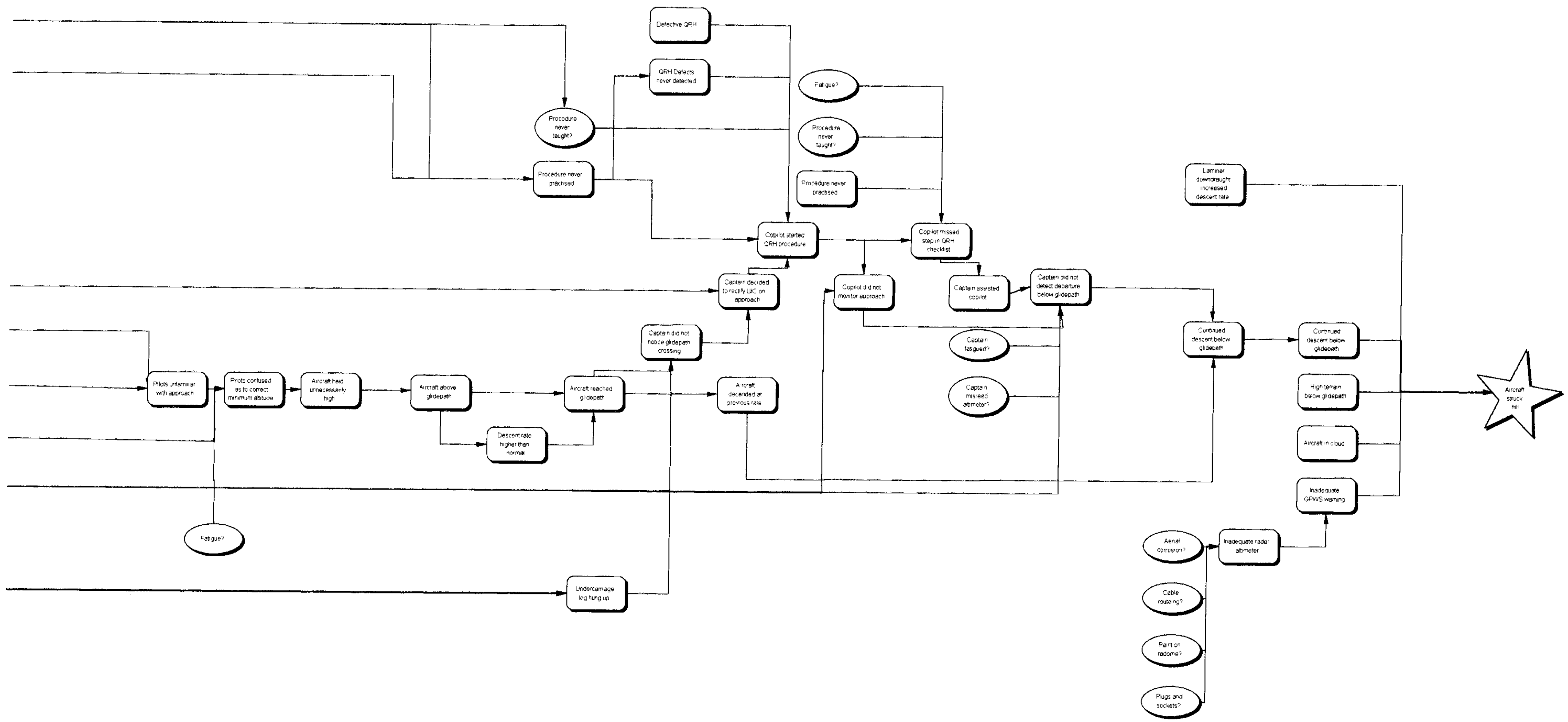
There are many more causal factors than the five identified in the official report. All are necessary to the accident, and in that respect none is more significant than any of the others. As CO Miller put it, "Down with probable cause!" (Miller, 1991). However, the Why-Because Graph can be very useful to identify core problems, if we regard our purpose (as we should) as averting future accidents. As to the links to corporate factors, the proof of the pudding is in the eating. Hard nosed corporate lawyers decided to settle out of court. Analysis leading back to the corporate factors in the accident pointed to the need for the Ansett Board minutes, to establish the reason for the abolition of the safety department. The absence of a safety department was a core problem which led to the various underlying conditions not being corrected, and to the crew being put into the position of making a series of errors that brought about the accident.

I would suggest that the pictorial format of the Why-Because Graph is easier to assimilate than the written format of the usual report. In particular, writing is essentially linear; but as you can see, the reality is a network, and this is almost impossible to put into words. A better report format might be to develop the graph, and lead the reader through it. Naturally, the supporting factual material must also be provided, but this could be relegated to annexes where it will be available to those who need it.

By presenting the report in a format that readers can assimilate, I think we would be much more likely to persuade those in a position to act on our recommendations, to do so.



Company making large losses
No Safety Manager
Considered "Not a safety matter"
Cost $20,000 US for fleet
Decision not to fit new design latches
Design faulty
No one monitored frequency
Up lock latch worn
Error by maintenance manager
Inadequate understanding by maintenance staff
Precursor events
Precursor events addressed by ad hoc fixes
Increasing frequency of precursors not recognised
Faulty instruction unrecognised in precursor events
Inspection instructions inadequate
Wear not detected by inspections
Cost of remote simulator training
No nearby simulator
Aircraft unavailable for training
No simulator training
No air continuation training
No written SOP
Company culture
No recurrent simulator training
No recurrent air training
Potentially confusing approach plate
No LOFT
Crew had ineffective CRM training


Defective QRH
QRH Defects never detected
Procedure never taught?
Procedure never practised
Fatigue?
Procedure never taught?
Procedure never practised
Copilot started QRH procedure
Copilot missed step in QRH checklist
Captain decided to rectify U/C on approach
Copilot did not monitor approach
Captain assisted copilot
Captain did not detect departure below glidepath
Laminar downdraught increased descent rate
Captain did not notice glidepath crossing
Pilots unfamiliar with approach
Pilots confused as to correct minimum altitude
Aircraft held unnecessarily high
Aircraft above glidepath
Aircraft reached glidepath
Aircraft descended at previous rate
Descent rate higher than normal
Captain fatigued?
Captain misread altimeter?
Continued descent below glidepath
Continued descent below glidepath
High terrain below glidepath
Aircraft in cloud
Inadequate GPWS warning
Aircraft struck hill
Fatigue?
Undercarriage leg hung up
Aerial corrosion?
Inadequate radar altimeter
Cable routeing?
Paint on radome?
Plugs and sockets?

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