Part III

Why-Because Analysis

(with Karsten Loer)

Chapter 11

Accident Analysis: Why-Because Analysis

We concentrate now on the causal analysis of incidents and accidents, which forms a part of CSA which we call Why-Because Analysis, or WBA. In this first chapter, we motivate WBA by showing how a formal analysis, even a relatively superficial one, can lead to important conclusions which somehow have been missed by society at large and its agents in the regulation and development of aviation.

We analyse two accidents, one occurring in Habsheim, Alsace, France in 1988, and one in Warsaw, Poland in 1993. The accident in Warsaw is covered in more technical depth later in Chapter sec:Warsaw-WB.

WBA is Causal Influence Analysis With Discrete Factors An accident has already happened; there is thus a history to discover and analyse. All fluents took on particular values, and some of these values and trends had causal effects on others. But the history is given: there are no alternative behaviors to consider. Therefore, all factors in the CID, here called a Why-Because Graph or WBG, are discrete factors.

Prophylactic Measures Become Easier to Determine Because all factors are discrete, prophylaxis consists therefore choosing a factor or factors and deciding what action(s) to take to ensure that these factors are omitted in all future similar cases.

11.1 A WB-Analysis of the 1993 Warsaw A320 Accident

On 14 September 1993, the Lufthansa Airbus A320 "Kulmbach" landed in Warsaw during a heavy rainstorm. It overran the runway, hit and overran an earth bank, and burned. Two people died, one pilot from trauma and a passenger, asphyxiated while unconscious. The accident report may be read in [Lad]. The points mentioned in this section are drawn from a longer paper [HL98]. The report cited probable cause as follows:

> Cause of the accident were incorrect decisions and actions of the flight crew taken in situation when the information about windshear at the approach to the runway was received. Windshear was produced by the front just passing the aerodrome; the front was accompanied by intensive variation of wind parameters as well as by heavy rain on the aerodrome itself.
>
> Actions of the flight crew were also affected by design features of the aircraft which limited the feasibility of applying available braking systems as well as by insufficient information in the aircraft operations manual (AOM) relating to the increase of the landing distance.

Making a WBG We arranged (with Michael Höhl) the states and events described in the official accident report into a WB-Script (a CI-Script for WB-Graphs). The WBG that resulted is shown in Figure 11.1.

Focusing In on Factors We can focus on the upper portion of the graph, where it narrows down to one node. This portion is shown in Figure 11.2. It is rare that a WBA of an accident results in a graph with a width of one. What is this single node?

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AC hits earth bank
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Take away this node, and you've avoided the accident. What are its immediate precursors?

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AC overruns RWY
Earth bank in overrun path
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The report's attribution of probable cause focused entirely on causal factors contributing to the first of these two events. What about the second? Why was there an earth bank in the overrun path? Because

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Bank built by airport authority for radio equipment
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Prophylaxis: Don't Overrun Or Don't Build So there is clearly something to consider. Don't build earth banks for radio equipment at the ends of runways in the overrun area. Or don't overrun runways. Well, measures are taken to minimise cases of the latter, but most authorities consider that no matter what one does, aircraft will still overrun runways once in a while. So if you want to prevent or minimise such catastrophic overrun accidents, one had better take the other option and not build in the overrun area.

Leaving Clear Overruns is Just Good Practice In fact, leaving a clear overrun area at the end of runways is regarded not only as good practice but as essential practice by most Western European and US authorities and by practically all pilots.

This Was Omitted from the Report's Conclusions The report's conclusions about probable cause and contributing factors said nothing about building earth banks in overrun areas.

This is Demonstrably A Mistake in Causal Reasoning The WBA of the accident shows clearly that this omission is a mistake in causal reasoning that the report made. The information necessary to infer it was a contributing cause was contained in the body of the report - that is where we obtained the factors in the WB-Graph in Figure 11.1. The WBA shows it to be a causal factor.

Rigorous Causal Reasoning Helps This is not the only causal reasoning mistake in the Warsaw report, neither is it the only report in which significant causal reasoning mistakes may be demonstrated by WBA. Another, the report on the 1995 American Airlines B757 accident on approach to Cali, Colombia is one, which also omits demonstrably causal factors in its statement of probable cause. The omitted factors in that report were, however, taken into account by the U.S. National Transportation Safety Board in their letter to the U.S. Federal Aviation Administration containing their safety recommendations based on their analysis.

Using rigorous methods of causal reasoning such as WBA would thus help considerably in ensuring correctness of these important reports. Prophylactic measures are based on the reports' analyses. It is important to reduce future accidents that resources be pointed in the appropriate directions, and one can only do this if a report's reasoning is correct.

11.2 The 1988 Habsheim Accident

On 26 June, 1988, an Air France A320, new into service with the airline, took off from Basle-Mulhouse airport with sightseeing passengers, intending enroute to put in an appearance at an airshow at the small airport Mulhouse-Habsheim, just a few miles and minutes flying time away. The pilot had planned for a "low-speed pass", a manoeuver in which the aircraft is configured for landing, flies low along the line of the runway very slowly without landing, and then accelerates up and away. This manoeuver was believed to show off the automatic slow-speed flight protection capabilities of the autopilot, and thereby how the performance of the airplane is enhanced. The manoeuver had been practiced at altitude by the pilot, from a more-or-less level entry.

The pilots had not surveyed the display airport before appearing, and had submitted incomplete flight planning to the Air France administration on Friday. The incomplete planning was approved, although some of it contravened French aviation-legal restrictions on airshow performances by commercial aircraft. These details are contained in the official report [Min89].

Upon takeoff, the aircraft climbed to an intermediate altitude of 1000 feet above the ground while the pilots identified the airshow airport, which should have been visible almost immediately upon takeoff. A descent was commenced towards the Habsheim airport, which reached a rate of 600 feet per minute with the engines in flight idle. The power setting at flight idle is 29% N1 (a measure correlating with the thrust produced) although the Commission noted that the manoeuver been planned starting from a high power setting.

As the aircraft approached for the low pass and passed through 100 feet above ground level (the planned fly-by altitude), the aircraft was still descending at a rate of 600 feet per minute with the engines in flight idle. The aircraft reached a low altitude of about 30 feet above the runway while attempting to perform the manoeuver. Beyond the end of the runway was a forest, with tree tops considerably higher. "Take-off/go-around" (TOGA) thrust was applied, but the aircraft continued level as the engines accelerated up to TOGA thrust, and the aircraft settled into the trees as the engines ingested tree parts.

Despite a jammed exit door, most passengers were able to leave the aircraft before it was consumed by fire from the burning fuel. Two young children and an adult (presumed to have gone back to help) died from smoke inhalation.

Figure 11.3 shows a WB-Graph causally relating the major features of the accident flight, including preparation, from the official report.

Controversy The accident became controversial when the captain, who was piloting the aircraft during the accident flight, publically asserted

- that the engines did not respond as designed to his TOGA thrust request;
- that about 4 seconds of recording data were missing from the flight data recorder (FDR) trace;
- that there were at least two different FDR boxes presented to the public as "the" FDR, and/or visible at the accident site
- that some of the data ostensibly from the FDR did not fit some of the facts about the flight;
- that required legal procedures for securing the FDR and taking it for analysis were not followed; insecure procedures were followed.

The captain wrote a book containing his version of the events, published a short while after the accident, and other books suggesting official miscreance have appeared. A decade later, another book about the events is planned to be published.

We may take it as uncontroversial that, had the engines reached TOGA thrust, say, some two seconds earlier, the aircraft would likely have avoided settling into the trees, and thus avoided the crash altogether.

Further Evidence There was a private video made of the accident fly-by by a spectator at the airshow. This video corroborated the altitude at various points of the fly-by, the timing of events, including (through sound-spectral analysis) the % N1 levels of the engines, the start of thrust increase on the engines, and the settling into trees.

The engines as certificated require up to about 8 seconds to increase from 29% N1 up to TOGA thrust. The official FDR data showed that they performed better than their certification parameters.

Evaluation of the Two Versions Our concern in evaluating the accident is to identify causes and other contributing factors in order to increase knowledge about safety-related aircraft and crew performance and to mitigate undesirable or unsafe features in future operations.

Thus the sole significant assertion for our purposes amongst those made by the captain is that the engines did not perform according to specification when TOGA thrust was commanded.

What difference would this make to the WB-Graph in Figure 11.3? Indeed, none at all. At the level of detail at which the major factors are stated, the only factor under dispute would be Factor 1.1, "*Very low TOGA performance*. Both versions agree this was so, although for different reasons. Both versions agree that the manoeuver was commenced at commanded thrust equivalent to 29% N1, and that the manoeuver had been practiced, and was usually conducted, commencing at much higher N1 levels. Both versions agree on the descent profile, and that the flight-idle power setting was a result of that. Both versions agree that the aircraft was piloted to within 30 feet of the runway, although the captain planned to overfly at 100 feet. The incomplete and partially legally unsuitable planning, and the lack of oversight, are likewise uncontroversial.

The Political Controversy As far as our interest goes, then, any dispute is about the exact level of TOGA performance, which disappears into the details when we are looking at the major factors contributing to the accident.

However, the high-visibility political controversy at the time was concerned not just with how the authorities may or may not have acted in the aftermath of the accident, but whether this "wonder aircraft", the A320, in fact could perform according to its manufacturer's and operator's claims. We can see clearly from the

WB-Graph that this latter dispute is a matter of mere technical detail as far as the accident is concerned; it does not affect the causal relations of the major factors at all. The asserted performance difference, while passing the Lewis semantic test for a causal factor, is a question of a finer difference that is subsumed within one of the major factors: it is undisputed that the TOGA performance of the aircraft did not suffice to avoid the trees. According to the official evaluation, it could not have been better. The captain thinks it could have been. That is all.

Had the status of this technical dispute been available and appreciated at the time, we can speculate that the major political controversy over the introduction of the A320 into service, following the accident, might have taken a much different form.

11.3 Conclusions

The two examples show that objective reasoning methods, had they been used during the investigation and ensuing controversy in these two cases, might have cast a very different light on things. If the methods of reasoning are not generally accepted and open to independent checking, then it is open to anyone to criticise and query for any reason they wish, and if two parties to a discussion reach significantly different conclusions, then there are no further ways of deciding the issues than deciding whom one believes. This is a highly unsatisfactory situation, and gives grounds for introducing objective reasoning methods. If reasoning methods are agreed to be rigorous and objective, then all parties to a discussion are bound to abide by the results.

Two questions: Do such methods exist, and how severe are the problems that stem from lack of rigor? Our use of the Lewis semantics for causality, and the related method WBA, show that the answer to the first question is yes.

The second question can be answered by considering what might have happened had a WB-Graph been available.

In the case of Warsaw, had a WB-Graph been constructed by the report writers based on the content of their report, they would have identified omissions in their statement of probable cause, and attention would have been brought to bear on the presence of an airport construction which adversely affected safety. Anecdotes say the mound is still there.

In the case of Habsheim, the heated political debate about the safety of the design of a new aircraft, and its consequences for public acceptance of the aircraft, might have evaporated, in favor of a technical performance debate and review of the sort which goes on every day at aircraft design and manufacturing plants.

Two anecdotes cannot prove a general hypothesis, but they may persuade. My purpose has been to persuade that objective methods of reasoning in accident evaluations are not just an exercise for academics. I believe they would have significant benefits, not only for accident investigation and the safety of air travel, but also for public debate as a whole.

There is another point worth remarking, again while taking care not to draw general conclusions from two individual cases. Both were publically high-profile accidents in which the digital automation on the aircraft was considered by many to have played a major contributory role. It is interesting to observe, when the causal reasoning is finally laid out, how few of the many factors involved in either of these accidents directly concerned the digital automation.

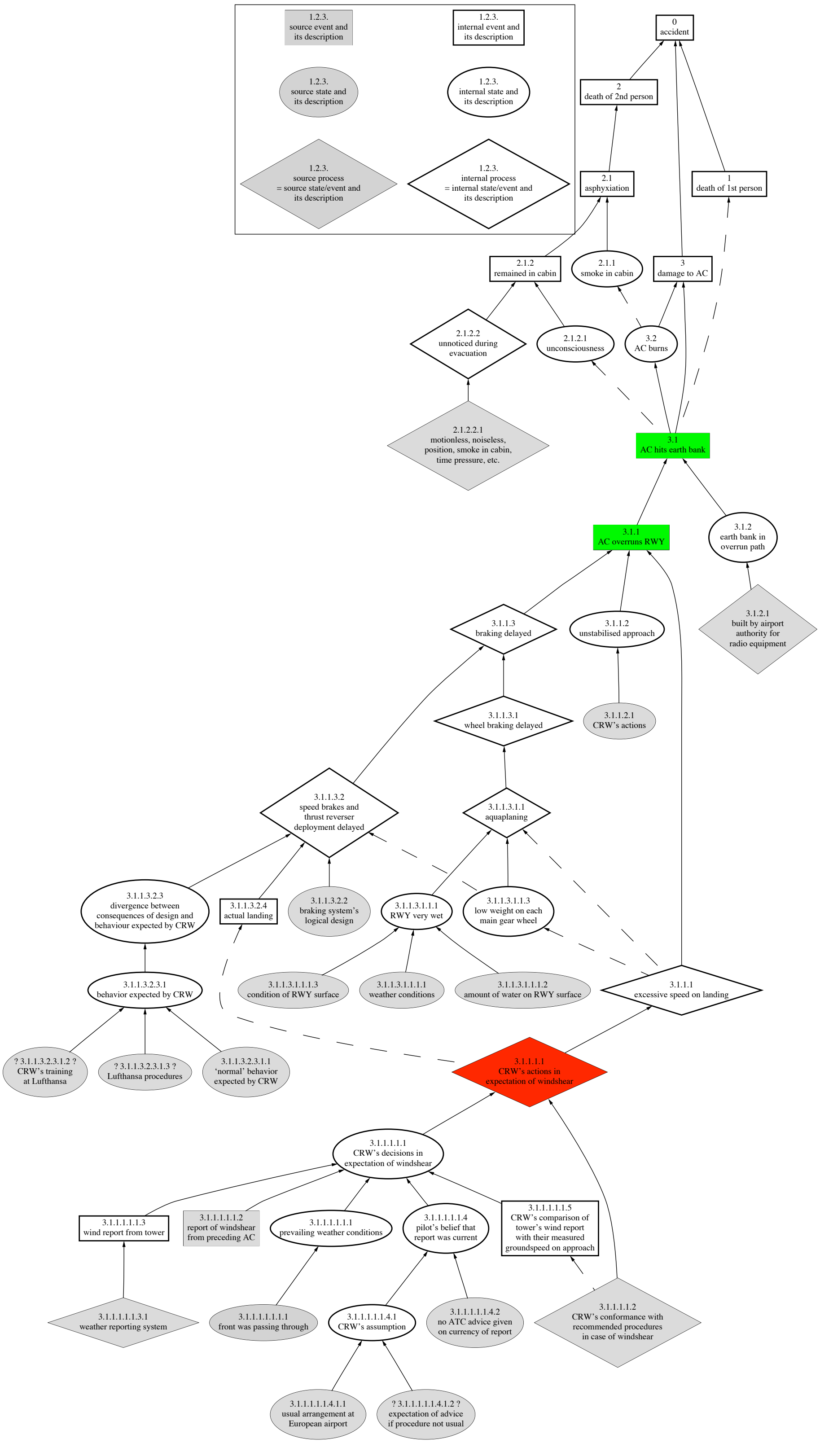

Figure 11.1: The Warsaw WB Graph

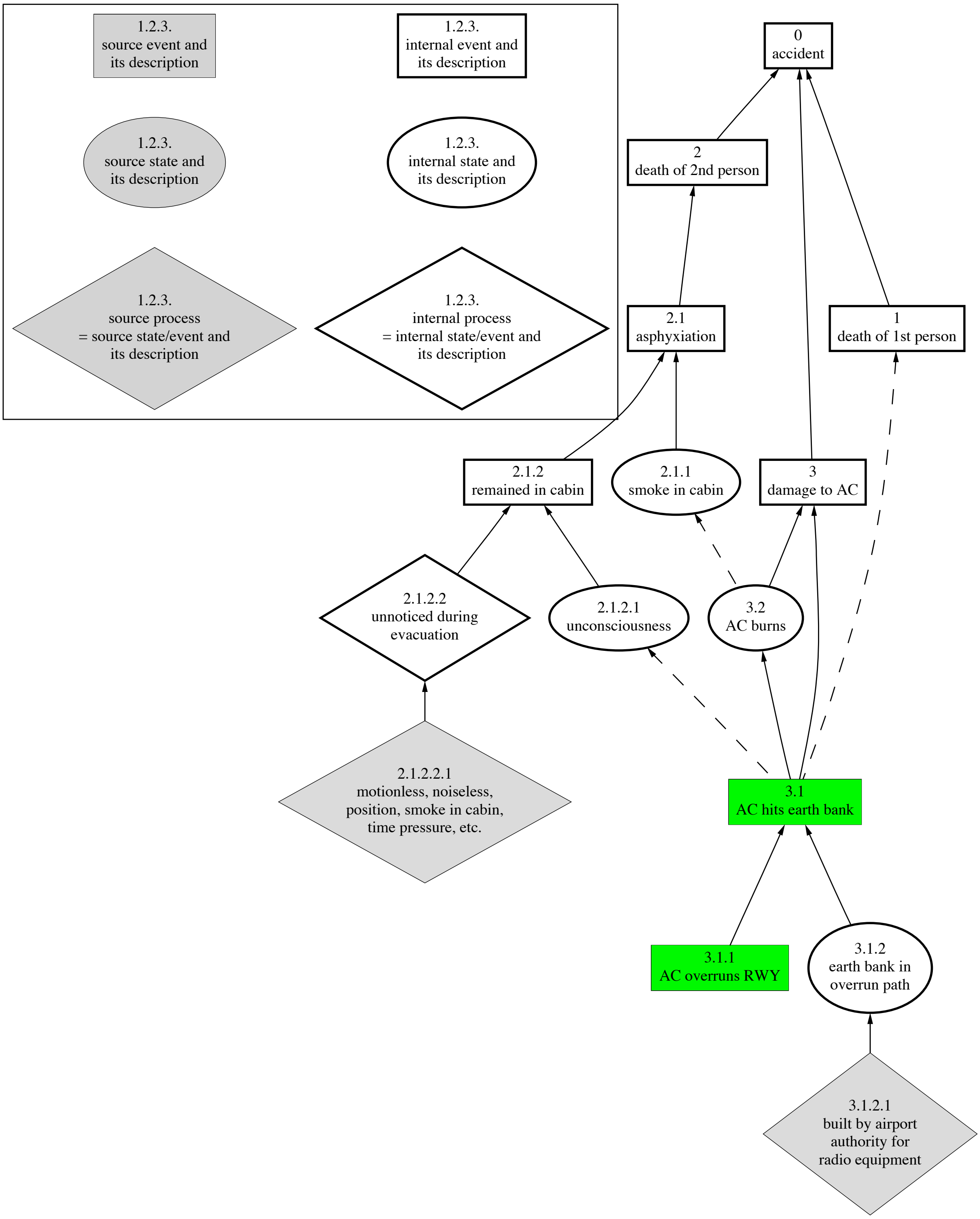

Figure 11.2: The Warsaw WB Graph, Upper Part

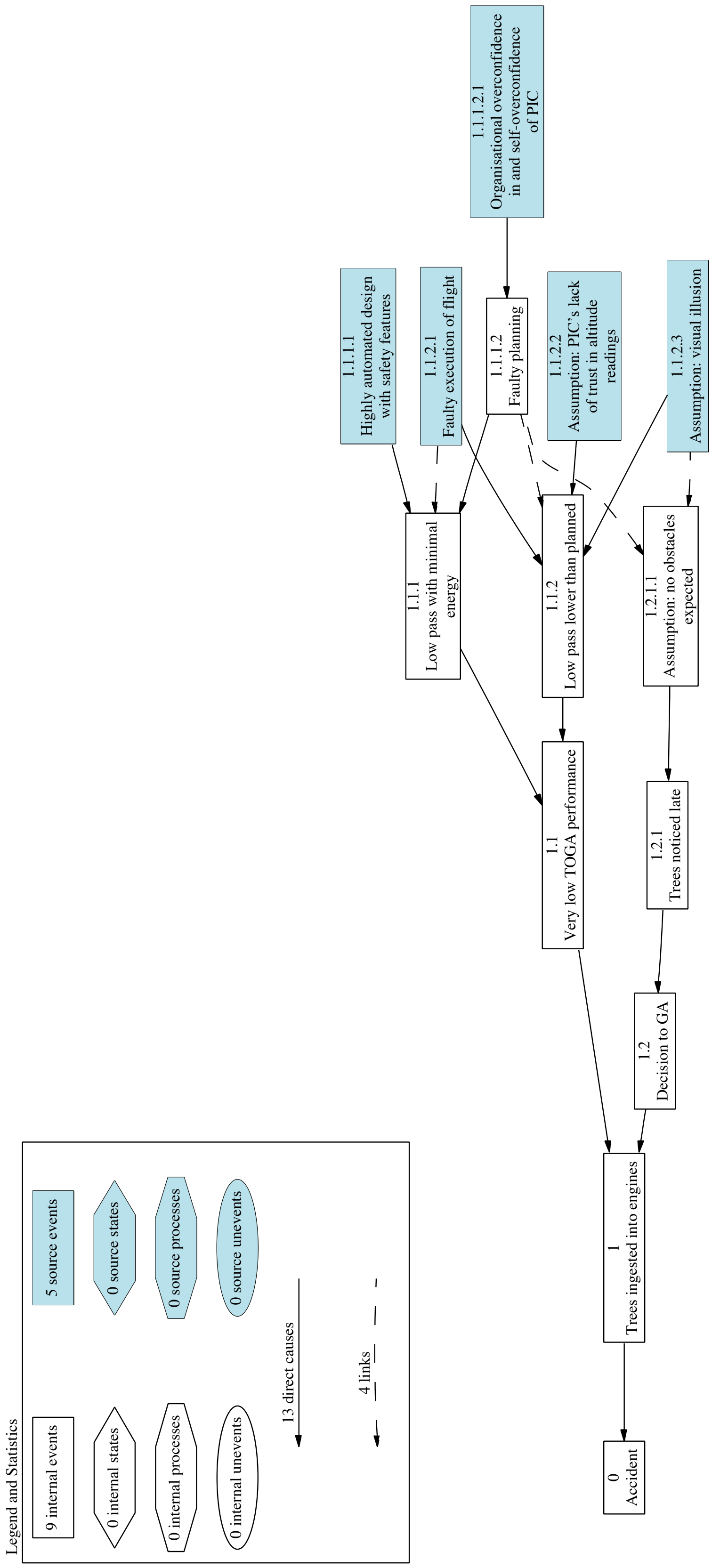

Figure 11.3: The Habsheim WB-Graph