**Technology Memo**

# The Minor Flaw Principle Applied to Aviation Disasters

Scott Jackson, PhD
jackson@burnhamsystems.net
Amandeep Singh, PhD
a82singh@uwaterloo.ca; amandeep.singh@polymtl.ca

**Abstract**: The posed minor flaw principle holds that minor system elements with flaws may contribute to disasters if the elements are part of major system functionality. Eight cases, with nearly 2000 fatalities, all of which illustrate this principle. This conclusion calls for, at a minimum, increased emphasis on detailed design and system integration.

**Introduction**. It has been observed that many aviation disasters have involved apparently minor aircraft system elements with flaws, or disrupted functionality. This observation has led to the conclusion that such system elements may have contributed to the disaster. It is further observed, through analysis, that the system elements were a part of major aircraft functionality. Major aircraft functions involved include climb, dive, and roll. It is therefore concluded that an interruption in major aircraft function is an essential aspect of disaster. In the following sections eight disasters are discussed, all of which involve minor element flaws interacting with major aircraft functions.

**Flaw**. This is a disruption in functionality for the system element. If the element is a minor system element, it is called a minor flaw,

**Functionality**. For this paper, the term *functionality* refers primarily to the major aircraft functions, such as climb, dive, and roll. It also refers to the ground movement and turning of aircraft on the runway. Finally, it refers to the functionality of the minor element involved in the disasters discussed. So, what this principle does, in short, this term links the functionality of the minor element, when appropriate, to the functionality of the aircraft, and when one is disrupted, both fail.

**Principle**. This is the posed principle which is the subject of this memo. This principle states, in effect, that if the functionality of a minor element is disrupted (a flaw), and that element contributes to major aircraft functionality (such as climb, diver, or roll), the disruption may act as a trigger that contributes to an aircraft disaster

This principle does not assert that all aviation disasters involve minor element flaws, nor that a minor flaw alone is sufficient to cause a disaster. However, all eight of the disasters described in this memo involved such flaws.

**The Trigger Metaphor.** A minor flaw is rarely causal in isolation. It is usually a trigger or a necessary but insufficient condition that exposes latent design, organizational, or operational vulnerabilities. The minor flaw is not a sole cause, but a trigger within a broader failure context.

**Case Studies.** In the following case studies, each disaster was found to involve minor flaw acting as a trigger within a broader system failure context.

**Tenerife (583 fatalities).** The primary case described is the 1977 collision of two 747 aircraft that collide on the runway on the Spanish island of Tenerife killing all occupants according to (Britannica, 2025). The final report lays the blame on the lack of communication and coordination between the two pilots, which can be interpreted here as minor functional disruption within the operational communication system (rather than as an isolated cause). The recommended action was improvement in terminology used by the pilots.

Although the overall fatality number for this study is nearly 2000, the Tenerife disaster stands out as the single most deadly disaster. So, the question is whether this disaster alone will drive future redesign efforts.

**737 Pittsburgh and Colorado Springs (382 fatalities)** In 1991 and 1994 two 737 aircraft crashed killing all on board. The official cause of the accidents was failure of a rudder actuator (FAA, 1994).

**737Max (346 fatalities).** The third disaster described by (Associated Press, 2025) is the 2018 and 2019 disasters in which two 737Max aircraft crashed killing all people on board the two aircraft. According to the report described in (Associated Press, 2025), a failed angle of attack sensor acted as initiating trigger, acted as the minor element failure that propagated through control logic to affect major aircraft functionality.

**Chicago DC-10 (1979) (273 fatalities)** According to the (NTSB 1979) this disaster involved an engine that fell off the aircraft due to a weak bolt in the engine support mechanism. This bolt was the minor element in this disaster. The recommended action was improved maintenance. This failure resulted in the uncontrollable roll of the aircraft, a major functionality.

**TWA 800 (230 fatalities)** In 1996 a Boeing 747 crashed into the Atlantic killing all people on board. The National Transportation Safety Board (NTSB, 1996) concluded that the probable cause was an explosion in the center wing fuel tank, likely ignited by a short circuit. The short circuit as defined by this paper constituted a “minor flaw” that resulted in the disaster. The recommended action was prevention of short circuits and inert gas in the wing tangs.

**Helios (121 fatalities)** In 2005, the Boeing 737 Helios disaster (FAA 2006), resulted in the deaths of all on board when the pilot failed to put the cabin pressurization system in the “auto” mode. This represents another “minor” flaw and this time due to “human error”. The recommended corrective action was installation of additional warning lights.

**Alaska - MD-83 (88 fatalities)** In January 2000 an Alaska MD-83 went down in the Pacific Ocean killing all people on board (FAA 2024). The component that failed was the jack screw that operated the horizontal stabilizer. The root cause of the disaster was determined to be inadequate maintenance. The recommended action was redesign.

**Comet (55 fatalities)** In 1954, two British-built Comet jet aircraft crashed killing all on board (FAA, 1953). The official cause of the crashes was structural failure due to metal fatigue catastrophic failure. In the context of this memo, structural failure counts as a minor flaw.

## Conclusion

This memo has added considerable thought to the mystery of how aviation disasters occur. But there is still lots of work to be done. What if the “minor flaw principle” provides a logical account of how disasters occur? The logical question then is: What do you do then? How can this principle be used to predict future disasters? And, even more importantly, how can it be used to prevent them? We leave the questions for future research and potential PhD thesis topics. We say again, the world is waiting for answers.

## References


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