

Supplementary material

**ANALYSIS OF GENERAL AVIATION FIXED-WING AIRCRAFT ACCIDENTS
INVOLVING INFLIGHT LOSS OF CONTROL USING A STATE-BASED
APPROACH**

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1. Conventional analysis of LOC-I accidents

We do a conventional analysis for LOC-I accidents where we analyse the relative frequencies with which NTSB codes are cited in accident reports. The NTSB uses occurrence codes to record the major events happened during the accidents and phase codes to record the phase of flight when the major event happened. We calculated the presence for each occurrence code (Occ_j) as the number of times it was used at least once in an accident, normalized by the total number of accidents (cf. Sorenson & Marais, 2016). Tables 1 and 2 show the most frequently cited occurrence codes in LOC-I accidents in 1999–2008 and 2009–2017 respectively.

$$presence(Occ_j|Accident) = \frac{\sum_{i=1}^{n_{accidents}} TRUE(Occ_j \geq 1 | Accident_i)}{Total\ Accidents} \quad (1)$$

In 1999–2008, 95.70% of the LOC-I accidents involved an inflight collision whereas 5.42% had a ground collision with terrain, water, or object. In 2009–2017, 75.89% of the LOC-I accidents cited a collision with terrain/object as one of the terminating occurrence codes. The post-2008 coding system does not have a separate code to describe inflight collision of aircraft. In 1999–2008, 2.58% of the accidents cited hard landing as compared to 4.20% of the accidents in 2009–2017. 2.40% of the accidents cited nose over in 1999–2008. The NTSB combined the nose over and nose down occurrences as one code in the post-2008 system 96: *Nose over/down* and cited it in 3.74% of the LOC-I accidents (not included in Table 2). The NTSB introduced a new code 90: *Abnormal runway contact* in the post-2008 coding system and cited it in 5.05% of the LOC-I accidents in 2009–2017. 12.21% and 10.44% of the LOC-I accidents involve loss of engine power in 1999–2008 and 2009–2017 respectively. The NTSB used five different codes to describe loss of engine power (total, partial, mechanical, or non-mechanical) in the pre-2008 coding system. Out of these five codes, the generic code 350: *Loss of engine power* was cited the most frequently (5.60%). In the post-2008 coding system, the NTSB has only two codes to describe loss of engine power, 341: *loss of engine power (total)* and 342: *loss of engine power (partial)*. Additionally, in 1999–2008, 6.11% of accidents cite forced landing as one of the occurrence codes. The post-2008 system cites 440: *Off-field or emergency landing* in 2.10% of accidents. Further, the post-2008 system uses the occurrence code 241 to describe aircraft stall or spin and is cited in 16.79% of accidents. The pre-2008 system did not have any stall or spin-related occurrence code and instead had two subject codes to describe stall/spin which is cited in 11.61% of the 1999–2008 accidents.

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Table 1. Top Ten occurrences in LOC-I accidents in 1999–2008

Occurrence Code	Description	Presence
230	In flight collision with terrain/water	76.57%
220	In flight collision with object	19.13%
240	In flight encounter with weather	8.88%
130	Airframe/component/system failure/malfunction	6.48%
180	Forced landing	6.11%
350	Loss of engine power	5.60%
320	On ground/water collision with terrain/water	2.95%
200	Hard landing	2.58%
310	On ground/water collision with object	2.47%
300	Nose over	2.40%

Table 2. Top Ten occurrences in LOC-I accidents in 2009–2017

Occurrence Code	Description	Presence
470	Collision with terrain/object (non-CFIT)	75.89%
241	Aerodynamic stall/spin	16.79%
300	Runway excursion	6.81%
400	Other weather encounter	5.79%
900	Miscellaneous/other	5.39%
60	Attempted remediation/recovery	5.33%
341	Loss of engine power (total)	5.22%
342	Loss of engine power (partial)	5.22%
90	Abnormal runway contact	5.05%
92	Hard landing	4.20%

Additionally, we identified the most frequently cited phases of flight for the occurrence codes 250: Loss of control – Inflight (in pre-2008 NTSB coding system) and 240: Loss of control – Inflight (in post-2008 coding system) by calculating the frequency percentage of phases of flight codes as shown in Tables 3 and 4. In both 1999–2008 and 2009–2017, initial climb was the most frequently cited phase of flight for LOC-I. Maneuvering is the second most cited and the third most cited phase (after takeoff) in 1999–2008 and 2009–2017 respectively. 6.90% of accidents in 1999–2008 and 14.74% in 2009–2017 involve LOC-I during landing flare/touchdown.

Table 3. Top Ten Phases of Flight for LOC-I in 1999–2008

Phase Code	Description	Percentage
522	Takeoff – initial climb	20.80%
580	Maneuvering	17.26%
565	Go-around (VFR)	6.97%
571	Landing – flare/touchdown	6.90%
540	Cruise	5.57%
564	Approach – VFR pattern – final approach	4.24%
553	Descent – uncontrolled	5.98%
573	Landing – aborted	3.22%
520	Takeoff	2.98%
560	Approach	2.84%

Table 4. Top ten phases of flight for LOC-I in 2009–2017

Phase Code	Description	Presence
350	Initial Climb	33.22%
300	Takeoff	22.84%
450	Maneuvering	17.54%
551	Landing – Flare/Touchdown	14.74%
452	Maneuvering – Low-altitude flying	11.49%
508	Approach – VFR Pattern Final	10.13%
509	Approach – VFR Go-around	4.77%
550	Landing	3.96%
402	Enroute – Cruise	3.96%
600	Emergency Descent	3.93%

References

Sorenson, D. & Marais, K. (2016). Patterns of causation in accidents and other systems engineering failures. In *IEEE Systems Conference*. IEEE, Orlando, FL. <https://doi.org/10.1109/SYSCON.2016.7490568>