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General Aviation Landing Incidents and Accidents:

A Review of ASRS and AOPA Research Findings

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Both of us were occupied with the task of...executing a downwind crosswind landing...Neither of us checked the "gear safe" light. Although neither of us are sure, the horn was probably sounding and we tuned it out...As always, do a GUMP check before every landing. (ASRS Report No. 84807)

Once things go wrong, they go wrong fast and get worse. (ASRS Report No. 83560)

Background and Motivation

In the Fall 1991 issue of its *Air Safety Report*, the Aircraft Owners and Pilots Association (AOPA) Air Safety Foundation published research revealing that 33 percent of pilot-related general aviation accidents between 1982 and 1988 occurred during the landing phase. Putting these landing mishaps into perspective, the Foundation cited a startling fact: "One percent of flying time suffers 33 percent of accidents."[2]

These findings motivated the Aviation Safety Reporting System (ASRS) to search its own database holdings of general aviation incident records. A preliminary search conducted in the fall of 1992 confirmed the existence of a large incident cluster associated with the landing phase in general aviation operations. Of 13,612 ASRS incident reports submitted by general aviation pilots between 1986 and 1992, 25 percent occurred during the landing phase. Preliminary analysis of these data suggested a relationship between landing phase incidents and factors such as training activities.

AOPA had earlier noted: "We have to continually ask ourselves why and how this phase of flight causes safety problems and examine those deficiencies that have brought so many pilots to grief."[3] To this end, ASRS undertook an extensive analysis of its data so that key safety issues in general aviation landing operations could be identified.

Objectives and Scope

Objectives. Specific research objectives were as follows:

1) Identify the results and operational causes of landing incidents in a study set of 150 ASRS reports, and compare these with landing accident results and causes identified by the AOPA Foundation;

2) Determine the key human and environmental factors contributing to landing incidents, and compare these with key accident factors identified by the Foundation;

3) Evaluate the hypothesis that training activities contribute to a significant number of landing incidents;

4) Drawing on collective ASRS/AOPA research findings, identify key safety issues in landing operations and potential solutions to these problems.

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2 *Air Safety Report*, AOPA Air Safety Foundation (Fall 1991).

3 Thomas A. Horne, "Retrospective: Landing Accidents," *AOPA Pilot* (November 1991):114.

Scope. So that ASRS incident data would reflect operational elements similar to those found in the AOPA Foundation accident data, the research team employed a two-tiered selection and screening process. During the initial ASRS database search, we applied selection criteria consistent with the Foundation's definitions of "general aviation" aircraft.[4] Thus, we excluded from database retrieval incidents involving aircraft with a gross weight of 14,500 or more pounds; incidents involving jet aircraft; and incidents involving air carrier operations under FAR Parts 121 and 135.

During the data analysis process, we used explicit rules of evidence as a secondary screening device to ensure that each report was relevant to study objectives. To be included in the study set, an incident had to meet each of the following criteria: 1) fit a strict definition of "landing phase" occurrence; 2) involve a "healthy" aircraft (one without fuel problems or severe equipment problems); 3) result in specific adverse consequences; and 4) involve an admitted or inferred pilot error.[5]

Approach

ASRS Data. The ASRS database contains more than 130,000 total incident records covering the 1986 to 1992 time period. An initial report set of 389 general aviation landing phase incidents from the periods 1986-1988 and 1991-92 was retrieved from the ASRS database. Reports were retrieved from two different time periods so that a portion of study data would be as consistent as possible with the 1982-1988 time frame of the Foundation's accident data. The dual time frame for the study set also enabled us to make statistical comparisons of the data.

Applying the secondary screening criteria described above, the research team selected 150 reports as a final study set. Eighty-two of these reports were from the 1986-1988 period; 68 were from the 1991-1992 period.

Properties of ASRS Data. ASRS data are influenced by both reporter and researcher biases. Reporters may introduce biases that result from their reactions to highly publicized accidents and incidents; from a greater tendency to report serious events than minor ones; and from many other factors. Researchers may inadvertently introduce biases in the recording and analysis of information in a study, even though coding protocols guard against this. All of these potential influences reduce the confidence that can be attached to statistical findings based on ASRS data. However, users of ASRS data may presume that incident reports drawn from a time interval of several or more years will reflect patterns that are broadly representative of the total universe of aviation safety incidents of that type. Since 17 years of research using ASRS data has not led to inexplicable or counter-intuitive results, this presumption seems reasonable.

AOPA Foundation Data. The AOPA Foundation Aviation Safety Database contains more than 16,000 finalized investigations by the National Transportation Safety Board (NTSB) on fixed-wing general aviation aircraft accidents that occurred from 1982 to 1988.[6] Our research team elected to use articles published by the AOPA Air Safety Foundation and *AOPA Pilot* magazine that summarized Foundation accident data.

Method. The research team developed a coding instrument that underwent several revisions during its development and was finalized following an interrater coding test. Once coding of the report set was completed, data were keyed into a relational database for initial tabulation, then transferred into a

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4 A partial exception was gross weight category. ASRS employs generic weight categories that differ from the weight criteria employed by AOPA. AOPA general aviation data were limited to accidents involving aircraft that weighed 12,500 pounds or less; ASRS data were limited to incidents involving aircraft that weighed 14,500 pounds or less.

5 Our coding definition of "landing phase"–the time interval in which the airplane is over the runway threshold, through the landing roll, and/or stopped–was consistent with that used by AOPA in compiling its accident data. By focusing on landing incidents involving "healthy" airplanes, we eliminated incidents in which pilot error usually was not a major causal factor (e.g., sudden equipment fires, seized engines); and also incidents rooted primarily in deficient pre-flight preparation (e.g., fuel exhaustion). Adverse consequences were those judged to be the most "accident-like" or severe in their potential to create an accident: aircraft controllability problems, aircraft damage, conflict with another aircraft, gear-up landing, near gear-up landing, or wrong runway approach/landing.

6 *Air Safety Report* (Fall 1991). At the time this paper was prepared, 1988 was the most recent complete year of finalized accident data in the AOPA Foundation Database.

spreadsheet program for final tabulations. Chi-square tests revealed statistically significant findings in one coding area. These findings are presented in discussion that follows.

Findings and Discussion

> *During the flare I heard an unusual noise (props hitting the runway) and effected an immediate go-around. The prop tips were curled about 3 inches both sides...* (ASRS Report No. 100149)

> *I followed another aircraft on final...I landed short behind him. Rather than run into him, I did a touch and go leap-frogging over him on my go-around...* (ASRS Report No. 173878)

Landing Incident Results and Causes. Table 1 classifies landing incident results for the two periods of study data and presents totals for each result category.[7] A chi-square test revealed significant differences in findings between the 1986-88 and 1991-92 data in two categories of landing results, "Other" and "Conflict with another aircraft." Succeeding discussion relates to the entire report set, except in those selected instances where the data from the two time periods diverge.

As Table 1 shows, a majority (63 percent) of the landing incidents resulted in aircraft damage, although the damage was not sufficiently severe to be classified as an accident according to NTSB criteria.[8] Prop strikes were the most frequently reported type of damage, followed by damage to gear doors and fuselage.

The AOPA Foundation had found that more than half of pilot-related general aviation accidents resulted in loss of directional control, or loss of control while landing in crosswinds, gusts, or tailwinds.[9] In comparison, 33 percent of ASRS landing incident citations involved some ***loss of aircraft control*** (this percentage combines runway excursions with loss of lateral directional control). ***Gear-up landings*** were the next most frequent result of landing incidents, with 31 percent of citations. Although we had expected to find a large number of gear-up citations, this category was proportionally much larger for ASRS data than for Foundation accident data.[10]

The "Other" category of landing results also accounted for 31 percent of total reports. "Other" was a catch-all in the coding instrument for landing results that did not fit into other categories, such as bounced or porpoised landings, violation of ATC clearances, gear collapse on rollout, and miscellaneous controllability problems (skidding, taxiway excursions, etc.). "Conflicts with another aircraft" was a separate coding category that represented 15 percent of all landing result citations. Table 1 shows that 1991-92 results in both the "Other" and "Conflicts" categories decreased substantially from 1986-88. Chi-square tests revealed that these shifts in data were statistically significant. The authors cannot satisfactorily explain these results. Inconsistencies in the coding process, or random statistical effects seem the most likely explanations.

In addition to classifying the results of landing incidents, we identified the ***pilot errors of commission*** (pilot actions) that directly caused these incidents. In order of frequency, these were improper control usage, destabilized and unstabilized approaches, mis-selection of runways or taxiways, and delayed initiation of go-arounds. These errors correlate closely with previous findings by the AOPA Foundation on causes of landing accidents.[11]

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7 "Miscellaneous" results were originally coded as discrete result categories, but were aggregated for presentation in Table 1.

8 NTSB regulation 830.2 defines an aircraft *accident* as an occurrence "...in which any person suffers death or serious injury, or in which the aircraft receives substantial damage." Substantial damage is further defined as "damage or failure which adversely affects the structural strength, performance, or flight characteristics of the aircraft, and which would normally require major repair or replacement of the affected component." Occurrences that do not meet these criteria are considered *incidents* of the type reported to ASRS.

9 Horne, 114.

10 This category accounted for approximately seven percent of pilot-related landing accidents, according to statistics supplied the authors by AOPA.

11 *Air Safety Report* (Fall 1991).

TABLE 1 [12]			
RESULTS OF LANDING INCIDENTS	**% 1986-88 Reports**	**% 1991-92 Reports**	**% Total Report Set**
Aircraft damage	63 %	63 %	63 %
Gear-up landing	34	26	31
Other	38	24	31
Runway excursion	13	24	18
Conflict with another aircraft	22	6	15
Loss of directional (lateral) control	11	19	15
Hard landing	7	18	12
Long landing	6	10	8
Short landing	4	10	7
Runway incursion	6	3	5
Miscellaneous (wrong rwy lndg, off-rwy lndg, ground loop, taxiway lndg, near gear-up lndg)	15	21	17
GRAND TOTAL	**219 %** (180 citations from 82 of 82 reports)	**224 %** (152 citations from 68 of 68 reports)	**222 %** (332 citations from 150 of 150 reports)

Pilot errors of omission (pilot inactions) were also identified. They included failure to extend landing gear, failure to monitor instruments prior to landing, failure to execute a pre-landing checklist, failure to maintain attention outside the cockpit during the landing phase, and failure to perform adequate preflight planning and preparation. The association between gear-up landings and the first three errors of omission is obvious.

Contributing Factors Cited by Reporters. Using several techniques–analysis of reporters' statements, and a human error taxonomy–we analyzed the factors underlying landing incidents.

The AOPA Foundation had previously identified several key human factors underlying landing accidents. These were pilot complacency ("I've landed in these conditions a hundred times"); impulsive decisions that ran counter to the dictates of previous training ("I can salvage this lousy approach"); and delay or failure in executing a missed approach or go-around.[13] AOPA had also pointed to pilot distraction as a factor in loss-of-directional control accidents.[14]

In comparing these findings with incident data, we first looked at ASRS reporters' own assessments of human and environmental factors underlying their landing events. Ninety-two percent of the reporters cited one or more contributing factors. ***Distraction*** was mentioned in 45 percent of the reports, almost twice as often as any other contributing factor.

Our coding instrument captured information on the source of the distraction, when this was offered by the reporter. Distraction by *external sources*–usually other aircraft, or ATC communications and handling–accounted for 57 percent of the distraction citations. One pilot asserted, "This incident resulted from pilot distraction. However, ATC contributed to this incident by changing their instructions from landing to go-around, back to landing...I had configured the aircraft for go-around and had retracted the landing gear and partial flaps when again I was cleared to land..." (ASRS Report No. 66294) Perhaps the ultimate distraction was suffered by a pilot whose eye glasses were blown overboard as he peered through the aircraft storm window to determine if the landing gear was down.

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12 Data depicted in Tables 1 and 2 were drawn from coding questions that permitted multiple responses, reflecting the fact that a single ASRS report often cited more than one landing result or contributing factor. Thus citation percentages exceed 100%.

13 *Air Safety Report* (Fall 1991).

14 Horne, 116.

Improper operating technique was the next most frequently cited contributing factor. This category included pilots' failure to use a checklist or a verbal pre-landing check; mis-selection of gear or flap switches; failure to check gear indications on short final; and improper attitude, altitude, or speed control.

Twenty-three percent of reports mentioned weather factors, and over half of these attributed landing problems to adverse ***wind conditions***. Crosswinds were the most frequently cited wind condition, followed by gusting winds and tailwinds. This finding lends support to AOPA's conclusion that "the fundamentals of maintaining directional control can't be emphasized too much"[15] during wind conditions. Further analysis of these reports determined that some landing incidents occurred because pilots had computed wind components incorrectly.

Pilots' ***preoccupation*** usually was with landing technique ("making a perfect landing"), cockpit tasks and activities, other aircraft, and in several instances with doors that had popped open.

Pilot inexperience was cited as a contributing factor in thirteen percent of the landing incidents. When we analyzed the entire study set in terms of reporters' total flight hours and time in aircraft type,[16] we made an unexpected discovery. *Time in aircraft type* appeared to be a much more important variable in landing incident occurrence than total flight hours. Of 109 reporters who provided information on time in type, 46 percent had less than 100 hours in type. Sixty-two percent had less than 200 hours. Of 139 reporters who reported their total flight time, the average (mean) flight time was 2,364 hours. Approximately three-fourths of this group fell in the zero to 1250-hour range. Thus, study data offer a refinement on the common wisdom that low experience is a risk factor for landing incidents. Specifically, it is the pilot with less than 200 hours in aircraft type who appears most at risk.

TABLE 2

CONTRIBUTING FACTORS	% Total Report Set
Distraction	45 %
Improper operating technique (checklist, gear, approach procedure)	28
Weather factors	23
Preoccupation	21
Miscellaneous other	18
Complacency	14
Pilot inexperience	13
Get-Home-itis	10
Fatigue	8
Lack of control response	8
TOTAL (283 citations from 150 of 150 reports)	**188 %**

In addition to reporters' own statements regarding the factors that contributed to landing incidents, we applied an error taxonomy derived from James Reason[17] to classify the *error tendencies* underlying errors of commission and errors of omission. These error categories were intended to capture information on perceptual and cognitive factors that underlay pilots' operational errors. A single report often involved more than one kind of error.

Attention failures were the leading error type, accounting for 46 percent of citations and correlating closely with reporters' mention of distraction. Decision errors, with 43 percent of citations, often related to pilots' failure to go-around on short final or during the pre-landing flare. Misperceptions were a factor in 38 percent of reports. For the most part these involved misperception of aircraft speed, altitude, or attitude. However, the study set contained one unusual example of a landing incident caused by a misperception: a pilot attempting to crank the gear manually "landed with the gear in the fully retracted position...[I] got counter-clockwise disoriented and cranked the gear in the wrong direction." (ASRS Report No. 89554) Short-term memory lapses accounted for 23 percent of the error citations. Many pilots admitted that their gear-up landings resulted because they had forgotten to use a written pre-landing checklist or the GUMP memory aide.[18]

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15 Horne, 117.

16 Information on hours "in aircraft type" is requested on the NASA/ASRS reporting form and reported according to how pilots interpret "type." Some may interpret "type" as aircraft model, others more generically as aircraft make.

17 James Reason, "A Framework for Classifying Errors," ed. J. Rasmussen, K. Duncan, and J. Leplat, *New Technology and Human Error* (New York: John Wiley and Sons, 1987), 5-13. We used only a portion of Reason's taxonomy that seemed most applicable to ASRS narratives. The authors are indebted to Sherry Chappell, the NASA/ASRS Research Director, for bringing this source to our attention.

18 For fixed-wing aircraft, "GUMP" is often taught as Gas-Undercarriage (Brakes)-Mixture-Power. For retractable aircraft, a popular version is Gear-Undercarriage-Mixture-Prop. Other variants of GUMP are also common.

Other Operational and Environmental Factors The research team examined operational and environmental factors that our collective judgment and experience indicated might predispose pilots to landing errors. These included the primary reporter's role as flying pilot or non-flying pilot, the existence of minor mechanical and/or equipment problems, and environmental factors.

Ninety-one percent of the reporters involved in landing incidents acted as the ***flying pilot***, while six percent were non-flying instructor pilots. When we looked more closely at the flying pilot group, we found that 80 percent were the sole occupants of their aircraft when the landing incident occurred.[19] Eleven percent of the flying pilots were either receiving or giving instruction; two percent were student pilots on solo flights; and six percent of this group did not provide enough information for us to be able to determine their role. Overall, there was a strong association between single-pilot operations and landing incident occurrence.

Although we had excluded incidents involving severe mechanical and equipment malfunctions from the study set, we found that ***minor problems with aircraft equipment*** were reported in 29 percent of the landing incidents. These included problems with gear system components, communication radios, electrical system components, aircraft doors, and other aircraft equipment. For some reporters, the problems with aircraft equipment were clearly a distraction. In one startling incident, a pilot selected the gear handle 'down' position, but "...the handle popped back up to its normal neutral position, and the knob and red light on the handle broke into 2 pieces and fell on the floor of the aircraft." (ASRS Report No. 100441) More typical was this pilot's experience: "At no time did the gear-up warning horns activate. After inspection, both were found to be inoperative." (ASRS Report No. 222206). Gear system-related problems accounted for more than one third of the reported equipment malfunctions.

The research team had expected ***environmental factors*** such as light conditions to be associated with some landing incidents. Twenty-four percent of the landing incidents occurred during less-than-optimal light conditions of dusk or nighttime. Another two percent occurred at dawn. Regardless of the time of day, however, 91 percent of all landing incidents occurred during Visual Meteorological Conditions (VMC).

Training Activities as a Factor in Landing Incidents. Analysis of data did not fully confirm a research hypothesis that a significant number of landing incidents occur during ***training activities***. Thirty percent of the study incidents cited training actvities. Forty-four percent of the pilots involved in training activities were engaged in self-training (practice) of landing maneuvers, consistent with the high number of single-pilot operations in the study set. Forty-six percent of the training pilots were with a flight instructor. However, when we compared the percentage of training-related study reports with the percentage of training-related general aviation reports for the entire ASRS database, we found that an even larger portion of general aviation database reports–39 percent–referenced training activities.

Conclusions and Recommendations

- **Aircraft Time-in-Type is a Risk Factor.** Analysis of general aviation landing incidents reported to ASRS resulted in a "profile" of the pilot most at risk for involvement in a landing incident. This pilot had less than 200 hours in the type of aircraft flown, was the sole occupant of the aircraft, and was involved in practice of landing maneuvers.
- **Loss of Directional Control Is a Major Factor.** Loss of directional control is a major factor in general aviation landing incidents and accidents. From the ASRS landing incidents studied, it was evident that many pilots were unable to recognize aircraft drift and correct for it in a timely manner. Analysis of incidents involving adverse wind conditions revealed further deficiencies in pilots' ability to compute wind components correctly. Study results underscore the need for pilots to establish personal skill levels for landing practice that are consistent with their ability to compute and handle varying wind conditions.

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19 If the reporter made no explicit or implied reference to the presence of another person on board, he or she was classified as a single-pilot occupant.

- **A Majority of Landing Incidents Involved Aircraft Damage.** Sixty-three percent of the landing study incidents resulted in aircraft damage. Landing "incidents" can inflict economic distress, even though events do not qualify as "accidents."

- **Gear-up Incidents Occur Frequently.** Gear-up landings were proportionally much more prevalent in ASRS incident data than in AOPA Foundation accident data. Many gear-up incidents and accidents could be prevented through use of a written pre-landing checklist or reliable application of memory aides such as "GUMP."

- **Gear System Problems Contribute to Landing Incidents.** Equipment problems and malfunctions were a contributing factor in almost one third of the general aviation landing incidents. Gear system malfunctions (warning horns, lights, and switches) accounted for a substantial portion of these problems. Pilots need to know how the gear system operates for each aircraft flown, and should check aircraft logbooks to determine when gear-retract tests were last performed. Gear warning horns, if installed, should not be disabled or "tuned out" during landing practice.

- **General Aviation Needs CRM.** Distractions and related attention failures are key factors in many landing incidents and accidents. Study findings support the conclusion that a "Cockpit Resource Management" (CRM) philosophy is needed in general aviation, especially in single-pilot operations. General aviation pilots should receive formal instruction in how to cope with multiple attention demands, prioritize tasks, and maintain cockpit discipline (use checklists and adhere to standard operating procedures).