Loss of Control – In-Flight: Upset Recovery Skills-Based Training

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Abstract

Loss of control – in-flight results in the greatest number of aviation fatalities in commercial and general aviation in the United States. Loss of control – in-flight is primarily the result of pilot error. Current regulatory requirements for recovery from loss of control – in-flight are inadequate and do not stress sufficient and recurrent basic flying skills necessary to prevent loss of control – in-flight. Augmenting current skills-based and adding scenario-based training to include a focus on stall/spin and over-banked instruction for Private Pilots, Commercial Pilots, and Airline Transport Pilots can reduce the number of fatalities associated with loss of control – in-flight accidents.

Loss of Control – In-Flight: Upset Recovery Skills-Based Training

CHAPTER 1

Loss of Control – In-Flight Defined

Loss of control – in-flight (LOC-I) conditions result in more commercial air carrier accidents than any other single factor in the United States. Seventy percent of the accidents associated with General Aviation (GA) aircraft, that is, non-scheduled air carrier operations, and specifically those airplanes that weigh no more than 12,500 pounds, are pilot related, with a preponderance of those falling into the LOC-I conditions. Improved and expanded upset recovery skills developed during Private Pilot and later Commercial and Airline Transport Pilot (ATP) certification can mitigate later airplane loss of control - in-flight occurrences.

The intended audience for this paper is the layperson with an interest in general and commercial aviation accident awareness and prevention. The paper presents an explanation of the LOC-I, a brief discussion of associated aerodynamics, and the realms of flight in which LOC-I can be encountered. Discussions on causal factors associated with accidents in both commercial and GA are presented. Human factors associated with accidents identify elements associated with pilot operations cause conditions that lead to LOC-I. Current training methodologies are discussed including regulatory testing requirements. The paper concludes with observations of noted aviation experts and recommendations for improved training methods.

Flight Conditions Leading to Loss of Control

This paper discusses loss of control in-flight (LOC-I) in reference to fixed wing aircraft. A fixed wing aircraft (herein referred to as an airplane), is an airplane that flies as a result of lift generated as a result of the aircraft's forward motion. Lift is the force generated by the wing that is perpendicular to the relative wind. Relative wind is described as movement of the atmosphere in relation to the airplane. "Loss of control" is a loss of control or unintended deviation by the pilot or crew of an airplane from the intended flight path. This deviation or loss of control from the intended flight path manifests itself within three basic realms of flight:

1. Stall
2. Spin
3. Overbanked flight

Stall

Stalled flight occurs when the angle between the chord of the wing (the chord line is an imaginary line between the wing's leading edge and its trailing edge) and relative wind exceeds the critical angle of attack (FAA, 2003, p. 3-20). The *Pilot's Handbook of Aeronautical Knowledge* identifies that the critical angle of attack is the angle where airflow over the wing's upper surface no longer conforms to the wing's surface, becoming turbulent, producing diminished and insufficient lift to support the airplane in flight. Additionally, the aforementioned handbook notes that in stalled flight, the airplane becomes unstable, often times exhibiting unanticipated responses to flight control inputs. In unaccelerated flight, e.g., straight and level flight path, the speed at which an airplane stalls, under given airplane weight configurations, is provided by the airplane's manufacturer, for example, the pilot operating handbook (POH) for the Cessna 172S, a popular training GA airplane, identifies these stall speeds in the Limitations section (Cessna, 1998, pp. 2-3 – 2-15). Similarly, some airplane manufacturers also provide accelerated flight stall speeds; however these are limited to motion about one of three possible axes of airplane motion, that is, bank also referred to as roll. The other axes as depicted in Figure 1 include pitch and yaw.

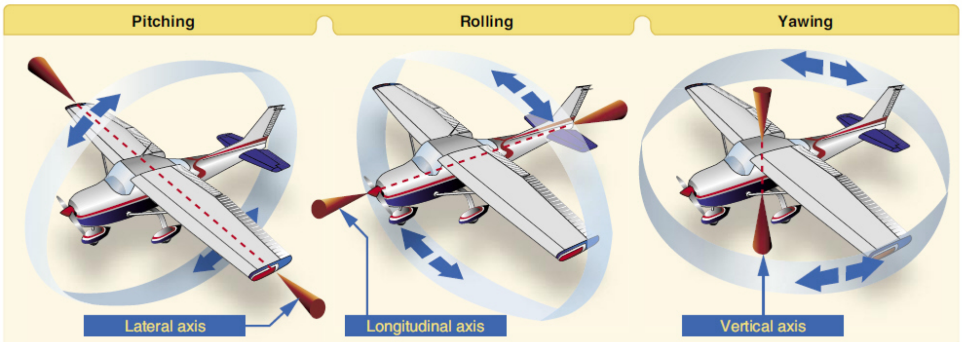

Figure 1 Three Flight Axes Note: Adapted from the Pilot's Handbook of Aeronautical Knowledge, by the Federal Aviation Administration.

An example of accelerated flight conditions under which manufacturers provide this information are during banked or turning flight (Cessna, 1998, p. 5-12). Stall speeds increase as bank angle increases (the higher the bank angle, the greater the acceleration, therefore the higher the stall speed). During the cruise phase of flight, where speeds are typically the greatest, there is little concern with stall, and little concern with accelerated flight, i.e., a constant airspeed is maintained, with little turning acceleration. One exception to this premise of high airspeed at cruise being far from stall speed is that of turbojet and turbofan power airplanes at high cruising altitudes.

One reason jet airplanes fly at high altitudes is that air density decreases as altitude increases allowing the airplane to fly much more efficiently and faster (NASA, 2004). Simply put, they go fast at altitude because the air is "thin." An American Scientific blog titled *Flying in the Coffin Corner–Air France Flight 447* discusses sub-sonic flight at high altitude and its potential pitfalls (American Scientific, 2011). The following discussion is paraphrased from that blog. The speed of sound decreases with increased altitude because temperature decreases allowing sound waves to more easily propagate. Sub-sonic jet airplanes, that is, airplanes flying at airspeeds less than the speed of sound, must fly below their critical Mach number (the maximum speed after which shock waves begin to form on the airplane and other significant aerodynamic problems develop). The downside here is that stall speed increases with increased altitude. Therefore jets at high altitudes operate near their critical Mach number to move their passengers as quickly as possible, while close to their stall speed. This area of flight operations was termed "coffin corner," named after the graphical plot of stall airspeed (expressed as a Mach number) versus altitude. Add accelerated maneuvering, a banked turn for example, and the airplane nears its stall speed. This is one reason that commercial turbojet airplanes use automation when cruising at high altitudes, operating almost exclusively on autopilot. "Hand flying" one of these airplanes at altitude takes a deft touch and knowledge about bank angle, accelerated flight, and proximity to stall speed.

Below the flight levels where jetliners cruise, the significance of accelerated flight becomes apparent as the airplane slows, for example, during the takeoff and the approach and landing phases of flight. Similar to those Boeings and Airbuses cruising near their respective coffin corners, airplanes operating during takeoff and landing phases of flight are intentionally flying slower than cruise, closer to stalled flight. Once again, add accelerated maneuvering flight, and the margins become thinner, and stall approaches. The LOC-I associated with stall becomes dangerously important as the airplane's distance from the ground decreases. To recover from stalled flight requires that the pilot understand that the airplane is in stalled flight and that the pilot applies the timely and correct control inputs to eliminate stall (decreasing the angle of attack, from critical, by applying forward elevator control, in up-right flight, and the addition of power to reduce the loss of altitude). These activities take time, and during that time, critical altitude is being lost (a discussion on response time is contained on page 17).

Spin

Spin is described as an aggravated stall resulting in auto-rotation (FAA, 2004, p. 4-12). Spin is the result of an airplane in stalled flight to which yaw and roll are coupled, referred to elsewhere in this document as stall/spin (Stowell, 2007, p. 188). Yaw is rotation about the vertical axis (Figure 1). As described in the *Airplane Flying Handbook*, when this rotation about the vertical axis occurs, one wing moves faster through the air than the other. The wing that moves faster produces more lift, consequently that wing rises and the airplane banks or rolls. This is referred to by Stowell as a "yaw-roll couple." When an airplane is aerodynamically stalled, adding yaw subsequently couples roll producing the noted auto-rotation and a spin. Spin in and of itself is not dangerous, if an airplane is approved for spin—transport category airplanes are not approved for spin, and many smaller, GA airplanes are also not approved for spin. These airplanes may not have the capability, i.e., the aerodynamic design features necessary to recover from spin (Stowell, 2007, p. 285). The danger is obvious for these groups of airplanes: Unrecoverable spin results in permanent LOC-I. For those airplanes which spin is approved, that is, those airplanes proven during type certification to be able to enter and exit from spin in accordance with FAA design requirements (FAA, 2011), two basic factors must be satisfied in order for the airplane to return to controlled flight. The *Airplane Flying Handbook* notes that first the pilot must recognize that the airplane has entered a spin state and must apply the necessary anti-spin control inputs and second, the airplane must have the available altitude for successful spin recovery.

Over-Banked

Banked flight causes an acceleration to occur as noted earlier. Lift developed by the wing is redirected during banked flight from a vertical to a horizontal vector, assuming up-right flight (FAA, 2004, 3-8). To maintain altitude, vertical lift must be increased. To do so, an increase in angle of attack is required. Both the acceleration of banked (turning) flight and the increase in angle of attack to maintain sufficient lift to maintain level flight, i.e., not descending, increases the load factor (weight) on the wing. This load is referred to as the g force (g referring to the force of gravity). In straight and level, unaccelerated flight, 1 positive force of gravity (+1g) is acting on the airplane. During acceleration, the g-load increases. G-loading in this instance increases as the angle of bank increases at a known rate (FAA, 2003, p. 3-30, -31).

Airplanes are rated for positive and minus g-loads depending on the category of airplane certification. Normal category airplanes, that is, many General Aviation airplanes, as noted in FAA Federal Aviation Regulation (FAR) Part 23 are certified for +3.8 g and – 2.0 g. Transport category airplanes as noted in FAA FAR Part 25 are certified for + 2.5 g (and up to +3.8 g's, depending on design takeoff weight) and – 1 g. However there are no published g-loads for rolling g's, that is, the g-forces the airplane is certified to sustain without structural damage during rolling flight. Over-banked conditions, identified as greater than 45° unintentional bank for transport category airplanes as noted in the *Airplane Upset Recovery Training Aid* (FAA, 2008, p. 2.1); however there is no published definition of over-banked flight for airplanes certified in other categories.

Recovery from banked flight is relatively straight forward: The pilot applies aileron and rudder inputs to return to level flight (FAA, 2004, pp. 3-7 – 3-13). Problems occur when over-banked condition exceed manufacturer published values and recovery is poorly executed, notably during rolling g events. Load limits can be exceeded and structural damage can be severe to catastrophic. Over-banked conditions can be pilot induced, for example shortly after takeoff to avoid an obstacle, a pilot may initiate a steep banked turn to avoid some trees or a radio antenna. Over-banked conditions may be inadvertently encountered as result of clear air turbulence or wake turbulence. These are defined respectively by the *Pilot's Handbook of Aeronautical Knowledge* as air mass movement without any visual clues such as clouds and wingtip vortices from other airplanes, most pronounced while those airplanes are flying heavy, clean (no lift devices extended such as flaps), and slow (usually near the ground during takeoff and landing phases of flight).

CHAPTER 2

Loss of Control – In-Flight: Root Cause Analysis

Boeing Commercial Airplanes collect statistics for scheduled, commercial air carrier operations (under FAR Part 121) airplane accidents (airplanes greater than 60,000 pounds maximum gross weight) and report their findings yearly (Boeing, 2011). The report includes worldwide operations (excluding the Commonwealth of Independent States, that is, former Union of Soviet Socialist Republics, and commercial airplanes used in military operations) using commonly flown transport category airplanes (a complete list is contained in the report). LOC-I is the number one cause of fatal accidents from 2001 through 2010 (Figure 2) with 1,756 onboard fatalities and 85 external fatalities.

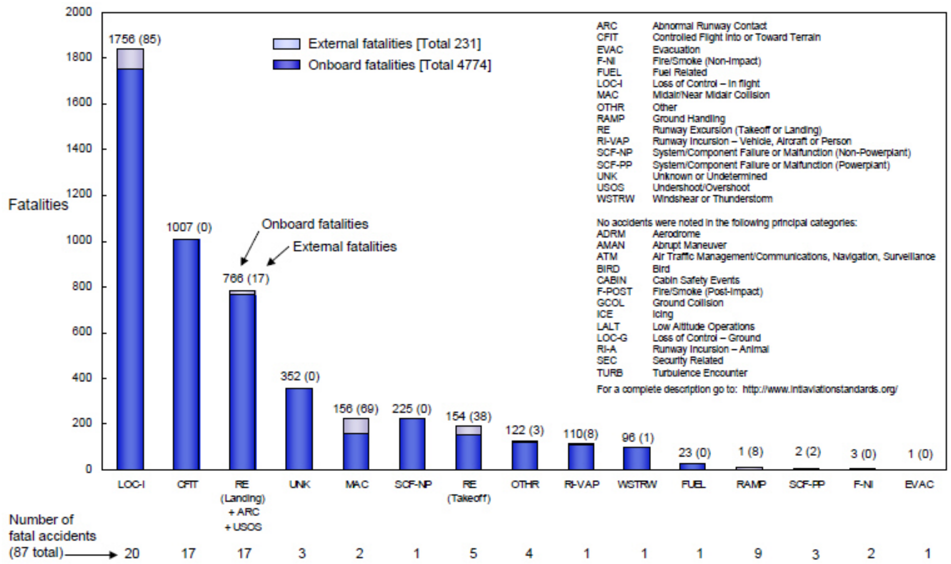

Figure 2 Fatalities by CAST/ICAO Common Taxonomy Team (CICTT) Aviation Occurrence Categories Fatal Accidents – Worldwide Commercial Jet Fleet – 2001 Through 2010. Note: Adapted from Statistical Summary of Commercial Jet Airplane Accidents Worldwide Operations 1959 – 2010

Recent and notable LOC-I accidents include Air France Flight 447, an Airbus 330, in June 2009 that departed from Rio de Janeiro, Brazil en route to Paris, France and crashed into the Atlantic Ocean after rapidly descending from 35,000 feet. Bureau d'Enquêtes et d'Analyses (BEA), the French equivalent to the National Transportation Safety Board (NTSB), *Interim Report No. 3* identifies that the airplane entered stalled flight shortly after a course correction to avoid probable, convective activity (thunderstorms). In spite of the efforts of initially two copilots, and then the captain, the airplane never recovered to controlled flight, impacting the ocean in a relatively level attitude at a high vertical rate of speed (BEA, 2011). Night, instrument meteorological conditions (IMC) and incorrect air speed indications, possibly due to ice could have combined to confuse the pilots and contribute to the stalled condition (BEA, 2011, p. 74).

On February 12, 2009 a Colgan Air Bombardier DHC8-402 Q400 (Flight 3407) approaching Buffalo Niagara International Airport crashed as a result of LOC-I and specifically an unrecovered aerodynamic stall (NTSB, 2010, p. 155). All fifty passengers and crew were killed. The airplane, like many transport category airplanes, was equipped with a “stick shaker,” a device that shakes the flight control yoke, notifying the pilots that stall is impending. The captain’s response, opposite to that of pilot training, was to pull back on the yoke versus push forward. This incorrect control input was, the NTSB notes, “inconsistent with his training and were instead consistent with startle and confusion” (NTSB, 2010, p. 152).

The *Joseph T. Nall Report of Accident Trends and Factors* is generated annually by the Air Safety Institute, an entity of the Aircraft Owners and Pilots Association Foundation (Air Safety Institute, 2010). These reports review the prior year’s GA accidents, as a result of reports gathered from the NTSB accident database. The Nall Report limits its scope to accidents in the United States and to general aviation, fixed wing airplanes weighing 12,500 pounds or less (and including rotorcraft, that is, helicopters, of all sizes).

General Aviation non-commercial fixed wing accident rates per 100,000 flight hours have slowly increased over the past ten years (Air Safety Institute, 2010, p. 7). Most accidents (70%) are pilot related, i.e., due to a pilot’s improper action or inaction.

Of the pilot-related accidents, landing and takeoff are the most often phases of flight where accidents occur (Air Safety Institute, 2010, p. 17). The 2010 Nall Report (Air Safety Institute, 2010, p. 22) notes:

> Loss of aircraft control remains the most common cause of takeoff accidents, accounting for 67, or 44% of the total. The deadliest type of takeoff accident was the departure stall, involved in 27% overall (41 of 153) but 60% of fatal accidents (15 of 25).

In addition to the landing and takeoff phase accidents are the “stalled/settled on takeoff” accidents, comprising 41 accidents and 27% of the total.

Although maneuvering flight accidents are second to takeoff and climb accidents, “more fatal accidents occur in maneuvering flight than any other pilot-related category” (Air Safety Institute, 2010, p. 22). The reason for this is that maneuvering flight is typically high enough above the ground such that failure to recover from loss of control has catastrophic consequences. Maneuvering can occur during takeoff, climb, cruise, approach, and landing phases of flight. The number one type of maneuvering accident is stall/loss of control, accounting for 52% of all (65) maneuvering accidents (Air Safety Institute, 2010, p. 24).

The two sources cited in this chapter, the Boeing Commercial Airplanes annual *Statistical Summary of Commercial Jet Airplane Accidents* and the Aviation Safety Institute’s *Nall Report* identify LOC-I as the predominant cause of aviation accidents.

CHAPTER 3

Causal Factor: Human Factors

Rich Stowell writes in *Emergency Maneuver Training*, “Pilot error, which is cited as a primary factor in most accidents, results from three elements influencing the pilot: distraction, faulty perceptions, and inappropriate control inputs” (Stowell, 1996).

Numerous causal factors are at the root of LOC-I: Human factors, including improper and missing training, automation confusion, distraction, loss of awareness; environment, including weather, wake vortices, foreign object damage; and systems-induced, including such elements as poor design, failed components, loss of control power, propulsion problems, etc. (NASA, 2005). The following discusses human factors as a causal factor in LOC-I.

Current Research

Improper and missing training includes fundamental piloting skills in the areas of stall recognition, entry, and recovery; spin recognition, entry, and recovery; and over-banked conditions. Stall recognition, entry, and recovery training occurs at the Private Pilot level instruction as noted in the FAR Part 61.107. After initial training for certification, no other training in this area is required. Review of stall can occur in a flight review, required every two years to maintain certificate currency. The contents of this review are primarily at the discretion of the Certificated Flight Instructor (CFI) performing the review in accordance with FAR 61.56. There is no flight training requirement for spins until one reaches the flight instructor level, and as noted earlier, this can be one-time, relatively short duration training, with no recurrent training required.

Overbanked condition recovery is peripherally encountered in primary flight training when learning to perform steep turns (bank angle from 40° to 50°) when bank angles increase beyond 50° and/or altitude is not held, resulting in an increased acceleration and potentially excessive load factors, as discussed in the *Airplane Flying Handbook* under *Performance Maneuvers* and steep turns (FAA, 2004, 9-1). Three hours of instrument flight training is required for a Private Pilot certificate. Within that training some portion of it must be "recovery from unusual flight attitudes" as noted in FAR 61.109. Using the definition for unusual attitude from the *Supplement #1 to the Airplane Upset Recovery Training Aid*, it is, a flight attitude that has a pitch attitude greater than 25° nose up or greater than 10° nose down, a bank angle greater than 45°, or combinations of these (FAA, 2008, p. 2.1). In addition to the unusual attitude recovery training embedded in the instrument instruction for a Private Pilot certificate, other training activities must be performed: "…straight and level flight, constant airspeed climbs and descents, turns to a heading, radio communication, and use of navigation systems/facilities and radar services appropriate to instrument flight" (FAA, 2011, 61.109). Only a small portion of the minimum three hours is devoted to unusual attitude recovery, and then, it is only performed in reference to the aircraft instruments, that is, there are no real-world, visual attitudinal references used to achieve controlled flight. These are instances when the pilot is hand-flying the airplane. When the airplane is being flown using some form of automation system(s), other problems can occur.

Automation is described as the "allocation of functions to machines that would otherwise be allocated to humans" (Funk, 1998). Funk identifies airplane automation systems as autopilots, auto throttles, flight directors, flight management systems (FMS), annunciation systems, and others. The use of these systems is intended to reduce pilot workload during the different phases of flight and, historically, such systems have reduced accidents (Boeing, 2010), yet issues associated with human interface to these systems cause problems, including but not limited to: understanding automation, automation behavior not apparent, pilot over confidence, poor visual and/or aural displays, and inadequate training (Funk, 1998, p. 120). All of these factors can lead to a loss of situational awareness (SA). The *Pilot's Handbook of Aeronautical Knowledge* (FAA, 2003, 16-8) describes SA as:

> The accurate perception and understanding of all factors and conditions within five fundamental risk elements (flight, pilot, aircraft, environment, and the type of operation that comprise any given aviation situation) that affect safety before, during, and after flight.

Endsley established a taxonomy of SA errors in an effort to identify training necessary to prevent accidents (Endsley, 1999). These SA error groups fall within "pilot" risk element and within the “aircraft” risk element, specifically that of aircraft design. Endsley argues that designs that take into account SA root cause can eliminate or mitigate such problems.

Endsley further identifies that as a result of a study of accident statistics gleaned from NTSB accident reports, most had some degree of loss of SA and most were from Level 1 which are defined with five sub-groups:

- Data not available
- Data hard to detect
- Failure to monitor/observe data
- Misperception of data
- Memory loss

Loss of SA can be a temporary event yielding no deleterious effect or it can yield catastrophic results, e.g., the crash of Eastern Air Lines Flight 401 due to loss of flight crew SA as result of troubleshooting efforts to determine the cause of a defective nose gear down indicator light resulting in 99 fatalities (NTSB, 1973). The earlier noted accidents, Air France Flight 447 and Colgan Air Flight 3407 are recent examples of loss of SA by the flight crew.

Psychological factors play an important part in the response to a loss of SA. Hilscher identifies one such facet of psychology is the element of surprise; “the impact of surprise is an outcome of the complex interaction between personality and situational factors” (Hilscher, 2005). A “diminished operational performance” results when an unanticipated event occurs and the surprise response is triggered. The psychology of surprise, defined as “the response to extremely rare events”, produces a lag in efforts by pilots to respond (Wickens, 2001). Wickens describes in *Attention to Safety and the Element of Surprise* a mean response time of 12 seconds and up to 18 seconds during an experiment associated with runway incursion, i.e., unauthorized intrusion onto a runway (Wickens, 2001, p. 2). Beringer identified it took pilots anywhere from 12.3 – 263 seconds to respond to a 25° – 30° bank angle as a result of autopilot malfunction (Beringer, 1997). According to Hilscher, response time (RT) and the effective management of surprising events has at its core four psychological elements (Hilscher, 2005, p. 5):

1. Alertness: There is a favorable arousal state at which one responds best to surprise events. Under or above this desired state of arousal and one's RT and response is unfavorably increased and incorrect, respectively.
2. Sense-making: The ability to make sense of a situation effects how quickly and what response is initiated. Hilscher describes this as "accurate cue perception."
3. Updating: The challenge of updating information with, for example, a defective nose gear indicator light, must be taken in context with the "big picture." Too much focus on one aspect of an event and other activities are compromised. This fixation, referred to as "tunnel vision" is diametrically opposed to effective filtering of information, i.e., updating.
4. Integration of Emotion and Cognitive Control: Hilscher describes emotions as "evolved situation-response tendencies…." Because a "relative sense of safety" is associated with aircraft and aircraft systems, any rapid "excursions into extreme conditions" are unanticipated, with little foreknowledge nor emotional preparation. An overload of emotions is possible in extreme situations, sometimes referred to as "saturation." This saturation has the potential to "disorganize and/or disrupt multiple psychological processes."

Loss of SA and the associated element of surprise due to conditions heretofore noted can lead to the LOC-I. Optimal levels of alertness, better sense-making, more inclusive updating, and the better a pilot is equipped to integrate emotion and cognitive control will yield better response time and favorable outcome.

Shortcomings of Current Training Methods

Primary flight training for the Private Pilot addresses some of the flight conditions that lead to LOC-I. These include: stall entry and recovery, over-banked flight recovery, unusual attitudes under simulated flight in reference to aircraft instruments (FAA, 2002). Unless scenario-based flight training is used, that is, "a training system that uses a highly structured script of real-world experiences to address flight-evaluation in an operational environment" (FAA, n.d.), rudimentary training is often learned by rote as a result the demonstrate-and-perform type learning facilitated by instructors. Scenario-based training is not currently mandated by the FAA. The context of where the stalled, spun, and over-banked condition may be encountered is discussed during flight training; however the real-world scenario where such conditions are encountered are rarely simulated and then sometimes associated with FAA/Industry Training Standards (FITS). The FAA Practical Test Standards (PTSs) are the documents used to determine the content and conduct methodologies of practical tests used to evaluate certificate applicants. The Private Pilot PTS identifies that the applicant must "exhibit knowledge of the elements related to power-off stalls" and "…power-on stalls " (FAA, 2002, pp. 1-27, 1-28). In addition to this, the Private Pilot PTS requires that the applicant demonstrate entry to and recovery from power-off and power-on stalls straight ahead and in turning flight. The Commercial Pilot PTS testing content is the same as the Private Pilot requirements. The Airline Transport Pilot (ATP) PTS testing requirements (FAA, 2008, p. 2-16) are less rigorous than the Private Pilot and Commercial Pilot PTS requirements, requiring only impending stall recognition and “impending stall (such as buffeting, stick shaker, decay of control effectiveness, and any other cues related to the specific airplane design characteristics) and initiates recovery” (FAA, 2008, p. 2-16). The ATP pilots are those that are captains on scheduled air carrier operations. One could make the argument that by the time a pilot has navigated through the ranks of certification, i.e., Private Pilot, Commercial Pilot, Airline Transport Pilot, he or she would have the necessary skill set and/or experience to recognize and recover from stalled flight. However, we see from documented accidents, e.g., Colgan Air Flight 3407 noted earlier, that this is not necessarily the case.

Spin awareness testing during practical tests as noted in their respective PTSs for Private Pilot, Commercial Pilot, and Airline Transport Pilot is an entirely theoretical discussion, that is, no requirements exist for the practical demonstration of spin entry, spins, and spin recovery. The following excerpt from the Private Pilot and the identical requirement for Commercial Pilot PTSs identify this requirement:

> Objective. To determine that the applicant exhibits knowledge of the elements related to spin awareness by explaining:
>
> 1. Aerodynamic factors related to spins.
> 2. Flight situations where unintentional spins may occur.
> 3. Procedures for recovery from unintentional spins.

There is no requirement for the applicant to at any time during flight training for the Private Pilot, Commercial Pilot, and Airline Transport Pilot to receive actual spin entry and recovery training. Of this pool of certificated pilots we see that those that most suffer fatal stall/spin accidents are the Private Pilots and Commercial Pilots (Figure 3). The conclusion behind Commercial and Private Pilots encountering high stall/spin accidents and not ATPs is that they (ATPs) are “the most experienced and knowledgeable pilots” and that Student Pilots, the fourth ranking fatal stall/spin group, are less likely to succumb to spin accidents because their flights are typically supervised by flight instructors (AOPA Air Safety Foundation, 2003).

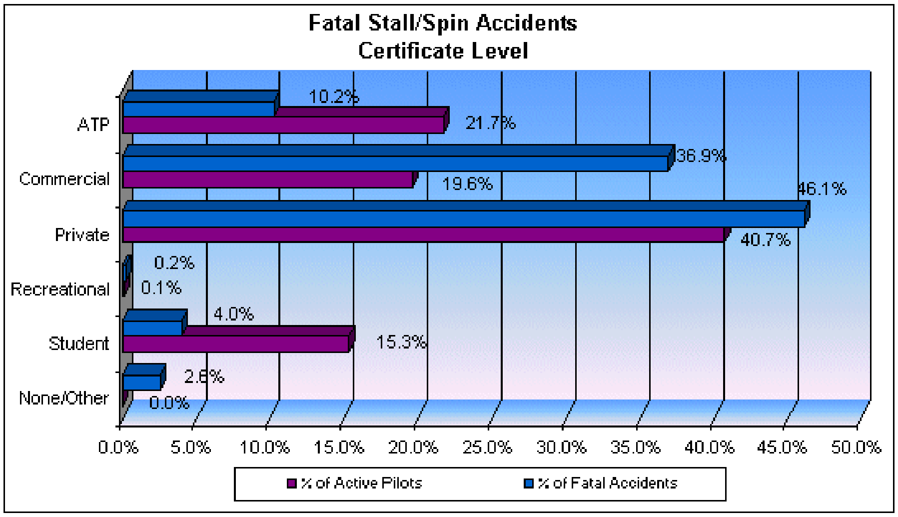

Figure 3 Stall/Spin Accidents by Certificate Level Note: Adapted from Stall/Spin: Entry Point for Crash and Burn?, by the AOPA Air Safety Foundation, 2003.

Demonstration of spin entry, spin, and spin recovery falls under the discretion of the examiner conducting the flight test for the certification of flight instructors. In lieu of actual testing, an examiner will accept an endorsement in the flight instructor applicant's logbook attesting that she has been given spin training (FAA, 2006, p. 1-56). A survey of recent literature, web forums, periodicals, and discussions with a small pool of flight instructors, anecdotally determined that only rarely is spin entry and exit testing conducted during a check ride for a flight instructor certification, and then only when the alternative training and endorsement did not occur. However it is at this level of FAA certification that a thorough knowledge of spin is encountered. The following excerpt from the Flight Instructor PTS defines this knowledge:

1. Exhibits instructional knowledge of the elements of spins by describing—

    a. anxiety factors associated with spin instruction.

    b. aerodynamics of spins.

c. airplanes approved for the spin maneuver based on airworthiness category and type certificate.

d. relationship of various factors such as configuration, weight, center of gravity, and control coordination to spins.

e. flight situations where unintentional spins may occur.

f. how to recognize and recover from imminent, unintentional spins.

g. entry procedure and minimum entry altitude for intentional spins.

h. control procedure to maintain a stabilized spin.

i. orientation during a spin.

j. recovery procedure and minimum recovery altitude for intentional spins.

2. Exhibits instructional knowledge of common errors related to spins by describing—

a. failure to establish proper configuration prior to spin entry.

b. failure to achieve and maintain a full stall during spin entry.

c. failure to close throttle when a spin entry is achieved.

d. failure to recognize the indications of an imminent, unintentional spin.

e. improper use of flight controls during spin entry, rotation, or recovery.

f. disorientation during a spin.

g. failure to distinguish between a high-speed spiral and a spin.

h. excessive speed or accelerated stall during recovery.

i. failure to recover with minimum loss of altitude.

j. hazards of attempting to spin an airplane not approved for spins.

3. Demonstrates and simultaneously explains a spin (one turn) from an instructional standpoint.

4. Analyzes and corrects simulated common errors related to spins.

The Flight Instructor certificate is the only FAA certificate that requires actual spin training to occur (although practical testing for this training is not required as previously noted). Often times, based on an informal review of a limited number of flight instructors that provide this training, spin training is accomplished in approximately two hours: One hour of ground school and one hour of flight instruction. There is no recurrent training requirement for spin training for Flight Instructors.

CHAPTER 4

Expanded Skills-Based Training in Flight Instruction

Spin training was mandatory in the United States beginning in 1926 when the Air Commerce Act established that the government could regulate civil aviation (Stowell, 2007, p. 21). However by 1949, as a result of the high number of stall/spin accidents (~50% of light aircraft accidents), and aircraft manufacturers lobby to “broaden the appeal of light airplane flying,” mandatory spin training was eliminated, instead replacing the activity with stall avoidance training and encouraging manufacturers to design more spin-resistant airplanes (Stowell, 2007, p. 26). No direct relationship has been established for the subsequent 50% drop in stall/spin accidents in the ensuing twenty years, however Stowell posits that improvements in airplane design and/or teaching methods may account for the drop.

In 1972 the NTSB recommended in Technical Report NTSB-AAS-76-4 that “the feasibility of requiring at least minimal spin training of all pilot applicants” be considered (NTSB, 1972). Hollister noted in *Identifying and Determining Skill Degradations of Private and Commercial Pilots* that those skills least practiced, i.e., stalls and instrument flight, resulted in the lowest score during an assessment of 55 Private and Commercial pilots. The report notes that "Most of the subjects had practiced these skills little or never since their initial training" (Hollister et al., 1973, p. 34).

Concluding that stall/spin and overbanked flight conditions can lead to loss of control, that a preponderance of aviation accidents result from pilot error resulting in LOC-I, the logical response should be how can LOC-I be avoided so that fewer accidents result? Hilscher notes that "field research shows that pilots who undergo upset-recovery training…are in a better position to handle a crisis, particularly the prevention of cascading or exacerbating problems" (Kilscher, 2005).

An industry working group, consisting of individuals "from the airline, manufacturer, regulatory, industry trade, and educational segments," was convened at the behest of the U.S. Department of Transportation, as a result of the recommendation of the NTSB as a result of investigated accidents, to educate pilots in preventing high altitude upset (FAA, 2008, p. 1). The guidance document, *High Altitude Operations Supplement #1 to the Airplane Upset Recovery Training Aid*, was created as a result of this effort. However training transport category pilots for upset events is not occurring within the airlines. As Fred George writes on the Aviation Week web site in *High-Altitude Upset Recovery*, "Pilots routinely get unusual attitude recovery training during simulator rides, but few if any Part 121 or Part 142 training organizations provide high-altitude upset or stall recovery training" (Aviation Week, 2011). Chesley Sullenburger, Captain of the "Miracle on the Hudson" Airbus that ditched in the Hudson River in 2009, added in the same Aviation Week article, "[Civilian] Pilots just don't get high-altitude upset training. They never have the chance to practice recovery maneuvers" (Aviation Week, 2011).

If the usually circumspect airline community is not providing this training that has been recommended by industry, the responsibility must begin where initial pilot training is encountered—in the Private Pilot, Commercial Pilot, and ATP regulatory requirements as mandated by the FAA.

Ken Elias, a retired airline pilot, ATP, Flight Engineer, former military pilot, and multi-engine CFI with over 17,000 hours flight time echoes Hilscher's position. When asked his position on the appropriateness of unusual attitude training he responded, "The knowledge of functions and limitations of flight controls requires an understanding of the aerodynamics of spins. For the professional (Commercial certificate or above), the ability to correctly recover from spins should be a requirement. For the Private Pilot, a complete discussion and a demonstration should be included in the syllabus. A proficiency in the recovery from an extreme nose-down attitude that might be encountered after a spin should be required of all pilots during certification and at the Flight Review" (personal communication, November 8, 2011).

This increasing level of knowledge for the increased responsibility of the Commercial and ATP certificate holder is repeated by Caleb Glick, a Washington D.C. based FAA Safety Inspector, who holds a Commercial Pilot certificate with over 10,000 hours in single-engine, multi-engine, helicopter, gliders, seaplanes, having performed flight instruction, aerial application, charter and on-demand operations. He notes, "Upset recovery, which includes spins, which are only required to be given to Flight Instructors, leaves a very important sector of commercial pilots lacking the ability to recognize and perform the flight control inputs to minimize or eliminate the impact of out of control spins. Requiring the commercial pilot to have upset training will create a pilot pool that has the experience for hands-on pilot upset experiences that will follow his or her aviation career through life. This will increase the safety factor for the flying public." He continues, "Aircraft today are not made to spin and recover at certification. Having a pilot trained to recognize and experience the onset, the actual spin, and recovery should be a required flight maneuver" (personal communication, November 9, 2011).

Skills-based and scenario-based instruction in unusual attitude recovery should be added to existing requirements for the examination of and certification for Private Pilots. This training would include current requirements for power on and power off stalls, adding spin entry, spin, and spin recovery instruction, and over-banked entry and recovery instruction. Like the examination and certification for the CFI, endorsements in lieu actual demonstration of unusual attitude recovery should be allowed to satisfy requirements contained in an updated PTS.

Commercial Pilots and ATPs should be held to a higher standard due to the commercial nature of operations and increased risk associated with carriage of passengers and cargo for hire. In this case, a greater breadth and depth of instruction is recommended, including the additional regimes of stall including: accelerated stalls (inducing stall in 45° banked turns), cross-control stalls (where flight controls are used in an intentionally uncoordinated manner), secondary stalls (stalled flight conditions after recovery from an initial stall), trim stalls (entry into stalled flight as a result of incorrect trim setting for the desired operation) (FAA, 2004, pp. 61 – 68). Spin training for the Commercial Pilot and ATP should include elements from the CFI PTS (p. 21), less the instructional emphasis, including:

- Aerodynamics of spin
- Flight situations where unintentional spins may occur
- Recognition and recovery from imminent, unintentional spins
- Entry procedure and minimum entry altitude for intentional spins
- Control procedure to maintain a stabilized spin

- Orientation during a spin
- Recovery procedure and minimum recovery altitude for intentional spins

Conclusion

More aviation fatalities are attributed to LOC-I events than any other single causal factor. Pilots are the major cause of LOC-I events in both commercial and General Aviation. Current training methodologies and regulatory requirements have done little to reduce the number one cause of aviation accidents. Those individuals studying the problem of human factors indicate that a focus on upset recovery indicates that positive gains will be realized with this type of training. Improving and expanding skills-based and scenario-based flight training for all certificated pilot levels will reduce the incidence of LOC-I and concomitant accidents and resulting fatalities. A paradigm shift is required to include definitive strategies and well-reasoned mechanisms for pilots to deal with LOC-I events. This shift would mitigate LOC-I aviation accidents that currently cause an unacceptably large number of fatalities.

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