MAINTAINING AIRCRAFT CONTROL

Randy Brooks, Jeff Edwards, Janeen Kochan, Paul Ransbury, Rich Stowell

June 20, 2012

Introduction

Becoming a safe, competent pilot requires proficiency in myriad physical and mental abilities. Regardless of a pilot's certification level, constant practice and refinement are needed to maintain those hard earned skills. Yet despite the overall effectiveness of the system of pilot training and certification in the United States, Loss of Control In-Flight (LOC-I) remains a significant cause of accidents and incidents in general as well as commercial aviation. This paper offers strategies to reduce loss of control accidents through improved education and targeted training, and provides information pilots can use to mitigate the risks associated with common LOC-I events.

Terminology

Regardless of the type of airplane flown or whether operating under 14 CFR Part 91, 121, or 135, all pilots are encouraged to adopt standardized terminology when discussing loss of control. The following are a few of the key terms:

- **Airplane Upset** refers to a departure from the intended flight profile that may or may not involve stalled flight, and that typically involves an excessive angle of bank, an excessive angle of pitch, or both, but that does not involve spinning. As a point of reference, the *Airplane Upset Recovery Training Aid* developed for air carrier operations defines an airplane upset as an airplane "unintentionally exceeding the parameters normally experienced in line operations or training" along with the following general guidelines:
    - A pitch attitude greater than 25° nose up
    - A pitch attitude greater than 10° nose down
    - A bank angle greater than 45°
    - Within the above parameters, but flying at airspeeds inappropriate for the conditions/phase of flight or maneuver

  While the reference to inappropriate airspeeds describes a number of undesired aircraft states, stalls fall into this category, though in that case the problem is directly related to angle of attack, not airspeed.
- **Loss of Control** refers to airplane accidents that result from situations in which the pilot should have maintained, or regained aircraft control, but did not. Loss of control is comprised of two components—in-flight (LOC-I) and ground (LOC-G). An analysis of incident and accident data reveals that LOC-I is the predominate component and will be the focus of this paper.
- **Normal Flight Mode** refers to a typical manipulation of the controls that results in the intended outcome of a flight operation, where the performance of that flight operation can be measured against a set of standards.
- **Unusual Attitude** is a broad phrase that includes, among other things, the unintended attitude that can follow an encounter with an inadvertent stall or spin, wake turbulence, or an uncommanded spiral. Unusual attitudes can arise as a result of pilot–airplane interface issues, inappropriate control inputs, or environmental factors.

For a more comprehensive list, please see http://uprta.org/terminology/.

History

According to the International Civil Aviation Organization (ICAO), loss of control in-flight (LOC-I) can be induced by the pilot, the environment, and/or system anomalies. Loss of control In-flight can occur whenever an aircraft is operated—intentionally or not—outside of its approved operating envelope, be it airspeed, roll, yaw, pitch, angle of attack (AOA), structural, and/or weight and balance limitations. LOC-I can also occur when a pilot's skill level has been exceeded, or when a pilot becomes fatigued, distracted, or is surprised or startled by an unexpected event. Furthermore, loss of control does not discriminate: it can and does happen to pilots at all levels of experience.

Accident Data

LOC-I outpaced other factors as the leading cause of fatal airplane accidents during the last 20 years. According to the General Aviation Joint Steering Committee (GAJSC), LOC-I accidents occurred nearly three times more often than Controlled Flight Into Terrain (CFIT) during the period 2001–2010. In fact, the LOC-I category contained a greater number of accidents than the next five categories combined. LOC-I dominated the three aircraft groups (homebuilt, turbine, reciprocating non-homebuilt) in the GAJSC analysis as well. Moreover, LOC-I events occurred most often during the maneuvering, approach, en route, and initial climb phases. LOC-I has not been a U.S. general aviation problem alone, but was the top cause of all commercial aviation accidents worldwide from 2001 to 2010 according to the Commercial Aviation Safety Team (CAST) and ICAO.

Pilot-Induced Upsets

The likelihood that an upset will lead to LOC-I is influenced by numerous factors, including pilot proficiency, alertness, weather conditions, aircraft energy state, capability, and/or complexity of systems. Human factors, however, remain the primary cause of LOC-I accidents, with distraction chief among them.

Inattention/Neglecting To Monitor Airplane Performance

Airplane upsets can often be traced to an improper instrument crosscheck, fixation, or failure to maintain good visual reference to the ground. At best, inattention or neglecting to monitor airplane performance can result in minor excursions from target parameters; at worst, it can result in extreme deviations from what was intended. For example, the FAA *Instrument Flying Handbook* describes two fundamental skills that must be developed during instrument training: instrument crosscheck and instrument interpretation. These two skills, properly executed, result in positive aircraft control when in instrument meteorological conditions (IMC.)

Diversion from Primary Flight Duties

Critical information can be misinterpreted or missed altogether whenever a pilot's attention is diverted from more urgent flight duties. The familiar saying "*Aviate, Navigate, Communicate*" is a popular checklist that delineates critical priorities for the pilot-in-command (PIC). Fumbling to set avionics or navigation equipment, or becoming preoccupied with an annunciator panel warning, for example, could distract a pilot sufficiently to lead to an inadvertent loss of control.

Spatial Disorientation

Spatial disorientation ("vertigo") has been a significant factor in many LOC-I accidents. As discussed in the chapter on Aeromedical Factors in the FAA Pilot's Handbook of Aeronautical Knowledge, all pilots are susceptible to sensory illusions and the hazards they can present, while flying at night or in certain weather conditions. LOC-I can occur when the pilot allows erroneous bodily sensations to dictate control actions rather than relying on accurate flight instrument indications.

Exceeding Pilot Capabilities

As discussed in the chapter on Aeronautical Decision-Making in the FAA Pilot's Handbook of Aeronautical Knowledge, the margin of safety is the difference between task requirements and pilot capabilities. Loss of control is possible whenever requirements exceed capabilities. For example, an airplane upset event that requires rolling an airplane from a near-inverted to an upright attitude may demand piloting skills beyond those learned during primary training. Or a fatigued pilot who inadvertently encounters IMC at night coupled with a vacuum pump failure could become disoriented and lose control of the aircraft due to the demands of extended—and unpracticed—partial panel flight. Unnecessary low flying and impromptu displays for friends or others on the ground often lead to pilots exceed their capabilities - with fatal results.

Startle Response

The all-too-human response to sudden, unanticipated events has traditionally been underestimated or even ignored during flight training. The reality is that untrained pilots will often have a startle response (i.e., an inappropriate psychological/physiological reaction) to an airplane upset event. Pilots can inoculate themselves against a debilitating startle response through scenario-based training. But to be effective, the controlled training scenarios must have a perception of risk or threat of consequences sufficient to elevate the pilot's stress levels. This will prepare a pilot to override the psychological/physiological reactions to an actual upset in favor of appropriate recovery actions.

Environmentally-Induced Upsets

Wake turbulence from other aircraft, turbulence caused by manmade obstructions and mountainous terrain, wind shear and icing have all resulted in airplane upsets and LOC-I (review the chapters on Aerodynamics of Flight, Airport Operations, and Weather Theory in the FAA Pilot's Handbook of Aeronautical Knowledge). These environmentally-induced upsets often occur in close proximity to the ground, and often while the airplane is at a slower speed and less maneuverable. This "low and slow" combination can make recovery from an upset difficult, if not impossible in many airplanes, even if the pilot is able to apply the appropriate recovery inputs. Hence, awareness and prevention are critical to avoiding upsets generated by environmental factors.

System Anomalies

Improvements in airplane design and equipment components have been a major focus in the aviation industry. Ever increasing reliability is a continuing effort; in spite of this, however, systems and components do occasionally fail. And since some of these failures can lead to loss of control, pilots need to be trained to mitigate or overcome the potential impact of such failures. The good news is most failures are survivable if timely corrective actions are taken.

Flight Instruments

Properly maintained, primary flight instruments tend to be quite reliable. Pilots can gain sufficient knowledge about flight instruments, common failure modes, and procedural alternatives through aircraft flight manuals, checklists, instrument manufacturer literature, and other sources. Remember, it is the instrument rated pilot's responsibility to maintain instrument proficiency and "partial panel" proficiency.

Automation

As discussed in the chapter on Aeronautical Decision-Making in the FAA Pilot's Handbook of Aeronautical Knowledge, automation includes the autopilot (and on larger transport aircraft, autothrottles) as well as systems that provide flight management and guidance (EFDs, MFDs, etc.). Unfortunately, some pilots can become over-reliant on their aircraft automation and thus become complacent about crosschecking and verifying information, or lose their hand flying instrument proficiency. Loss of control has occurred when automation has failed and the pilots have been unable to trace the cause of the anomaly, or have been unable to revert to more fundamental flying skills.

Advanced automation systems in particular can mask the cause of an automation anomaly. Therefore, pilots should consider reducing the level of automation (e.g., disengage the autopilot) to maintain or regain control of the aircraft should an anomaly occur.

Sensory Overload/Deprivation

Pilots who are faced with airplane upsets may often be confronted with multiple visual, auditory, and tactile warnings. A pilot's ability to adequately sift through the data being presented by simultaneous streams of warnings, annunciations, instrument indications, and other cues, however, can be limited. The ability to separate time-critical information from the rest takes practice and an intimate knowledge of the airplane and its systems.

On the other hand, expected or anticipated warnings occasionally may not be provided when indeed they should be. Crosschecks are necessary not only to corroborate other information that has been presented, but also to determine if information might be missing or invalid. For example, an in-flight stall warning system failure that is unable to warn the pilot of close proximity to a stall while executing a turn with airspeed rapidly approaching the wings-level stall speed may be averted through other methods. Though the pilot may not be receiving an electronic stall warning, aeronautical knowledge about the relationship between bank angle and stall speed along with experience performing similar turns in the past provide clear evidence of an impending stall. Also, aerodynamic cues like airframe buffet may provide a tactile cue of an impending stall.

Flight Control and Other Anomalies

Anomalies involving the flight controls (e.g., flap asymmetry, malfunctioning flight controls, runaway trim) may be addressed in detail in aircraft flight manuals, but generally are not covered during primary flight training. These and other anomalies may require the use of alternate control strategies to prevent or recover from an associated upset.

Operating Envelope Excursions

However induced, an airplane upset in and of itself does not necessarily culminate in a loss of control accident. Recovery to a normal flight mode needs to be initiated as soon as a developing upset condition is recognized. The amount and rates of control inputs and power adjustments necessary to counter an upset must be in direct proportion to the amount and rates of change of roll, yaw, pitch, and/or airspeed experienced. Early recognition of an upset scenario coupled with appropriate preventive action often can mitigate a situation that otherwise could escalate into a loss of control.

However, it must be understood that not all upsets can be guaranteed to be recoverable even if time and altitude are available, and in some cases, even if the proper recovery technique has been applied. For example, a pilot who is an unnecessarily anxious flyer and thus systematically avoids banks greater than 30 degrees (the pilot's operating envelope) may become incapacitated by fear and unable to recover when confronted with an inadvertent, steep spiral. Similarly, loading an airplane beyond its aft center of gravity limit (the airplane's operating envelope) could prevent a pilot from being able to lower the nose during takeoff (or recovering from an ensuing departure stall) no matter how strong the pilot may be (or how proficient with stall recovery).

Upset Prevention and Recovery Training

Pilots who find themselves outside of their "normal operating envelope" or in conditions beyond their training experience are often unprepared to avoid a loss of control during an upset event. In fact, a pilot's prior exposure to, and competency with, upset prevention and recovery training (UPRT) scenarios are perhaps the largest predictors regarding whether or not an upset will culminate in an accident. It is for this reason that pilots are encouraged to obtain as much aeronautical and practical knowledge as possible about common upset scenarios. It is imperative for pilots to arm themselves with the capability not only to recognize and avoid potential upsets, but also to safely recover from a developing upset event.

Core Concepts

Airplane upsets are by nature time critical events; they can also place pilots in unusual and unfamiliar attitudes requiring counterintuitive control movements. Upsets have the potential to thrust a pilot into a life threatening situation compounded by panic, diminished mental capacity, and potentially incapacitating spatial disorientation. Therefore, exposing pilots to common LOC-I scenarios in a structured environment is essential so they will be able to learn to squelch their natural startle response in favor of promptly implementing the appropriate recovery procedures. Properly administered, such training instills the knowledge and confidence needed to successfully deal with abnormal flight situations.

By introducing different levels of UPRT at the proper stages in the pilot certification process, trainees are given an opportunity to gain increased familiarity and confidence. It is also crucial for UPRT concepts to be conveyed accurately and in a non-threatening manner to achieve maximum effect. Reinforcing concepts through positive experiences from the outset significantly improves a pilot's depth of understanding, retention of skills, and desire for continued training.

Regardless of the type of aircraft flown, UPRT exposes pilots to a broad range of concepts and experiences that are applicable to a variety of LOC-I scenarios. The goal should be the ability to recognize an escalating threat pattern or sensory overload, and properly identify and correct an impending upset. Comprehensive UPRT builds on three mutually supportive components: academics, use of flight simulation training devices (FSTDs), and aircraft-based training. Each offers unique benefits;

each also has limitations. But when implemented together, the components can offer maximum preparation for upset prevention, avoidance, recognition, and recovery.

Academics

Academic exercises are the foundation from which knowledge and skills evolve. It is important here not only to introduce UPRT material in the proper sequence, but also to use proper terminology and proven methodology—context and consistency are key here. With solid academics in place, simulator- and aircraft-based environments become the laboratories in which to put UPRT concepts into practice. While this overlapping approach offers benefits in virtually all areas of flight training, it is particularly beneficial when addressing the complexities and nuances associated with airplane upsets and LOC-I.

Although academic preparation alone may offer a limited level of mitigation of the LOC-I threat, long-term retention and greater levels of awareness and mitigation are achieved when academics are integrated with hands-on experience.

Flight Simulation Training Devices

Simulation provides another useful level for the conduct of UPRT. Continuous G or spatial disorientation simulators, fixed-base simulators, and full flight simulators might be employed for different elements of this training. For example, the use of a type-specific, full flight simulator enhances the practical skill development associated with that type's systems and performance. Yet while each of the platforms mentioned can and does serve specific purposes, it is important to understand the technical and physiological boundaries when using a particular FSTD for upset training.

Examples of boundaries might include a limited ability to demonstrate yaw–roll coupling from a cross-controlled stall configuration, or an inability to accurately replicate roll instability at high AOA. Simulator training also may not be able to reproduce the same vestibular and physiological inputs a pilot could experience during real-life upset events. Consequently, pilots who only receive upset training in FSTDs may not be able to make sense of such unfamiliar, conflicting, or confusing information during an actual upset. Potentially incapacitating cognitive disorientation could result, leading to LOC-I.

Aircraft-Based Flight Training

Ultimately, the more realistic the training scenario, the more indelible the learning experience. Although creating a visual scene of a 110° banked attitude with the nose 30° below the horizon may not be technically difficult in a modern simulator, the learning achieved while viewing that scene from the security of the simulator is not as complete as when viewing the same scene strapped in an airplane in flight. The acquisition of skills related to correctly responding to an undesirable aircraft state is fundamental to executing a safe recovery, and maximum learning is achieved when placed in the controlled-yet-adrenalized environment of upsets experienced while in flight. Upset prevention and recovery training improves a pilot's ability to overcome fear in an airplane upset event. Through exposure to the upset environment in training, the pilot can be better prepared to not only take effective correct action in a developed upset but also, through awareness and avoidance, intervene in an escalating event sooner than without UPRT knowledge and skill.

Yet even aircraft-based UPRT is not without limitations. The level of upset training possible may be limited by the maneuvers approved in the particular aircraft as well as the flight instructor's own UPRT capabilities. For instance, UPRT conducted in the Normal category by a typical CFI will necessarily be different from UPRT conducted in the Acrobatic category by a CFI who has expertise in all attitude flight.

When discussing upset training conducted in aerobatic-capable aircraft in particular, the importance of employing instructors with specialized UPRT experience in those aircraft cannot be over emphasized. As much as instrument or tailwheel instruction each demand specific skill sets for those operations, UPRT likewise demands that the instructors possess the competence to oversee trainee progress (and be able to intervene if necessary) with consistency and professionalism. On the other hand, the improper delivery of stall, spin, and UPRT often results in negative learning, which could have severe consequences not only during the training itself, but in the skills and mindset pilots take with them into the cockpits of airplanes where the lives of others may be at stake.

Awareness and Prevention

UPRT concepts are best introduced during the certification phase of training. Striving to heighten awareness early makes pilots less susceptible to conditions that could lead to an upset and is an essential building block for accurately assessing risk and acquiring and employing upset recovery skills. For example, operation at high AOA tends to be less familiar to (and uncomfortable for) many pilots since it is seldom encountered during routine flight operations; many LOC-I accidents, however, involve high AOA departures from controlled flight. Thus, developing a deeper awareness of the relationship between AOA, G-load, lift, energy management, and the consequences of their mismanagement is a special emphasis area in UPRT.

The prevention side of UPRT covers information specific to recognizing and avoiding hazards commonly associated with aircraft upset and LOC-I events. Prevention training generally focuses on two aspects: prevention through better aeronautical decision-making (ADM), and prevention through proportional counter response.

Aeronautical Decision-Making

Effective ADM, as discussed in the chapter on Aeronautical Decision-Making in the FAA Pilot's Handbook of Aeronautical Knowledge, is accomplished through analysis, awareness, resource management, and ultimately, the breaking of an error chain early through situational awareness, sound judgment, and basic airmanship skills.

Proportional Counter Response

Proportional counter response is the timely manipulation of flight and power controls, individually or in combination, to manage an unplanned excursion in aircraft attitude and/or the flight envelope. An aware pilot recognizes a developing threat and responds accordingly. The time available for a pilot to counter a developing upset may be a matter of seconds, yet the trained pilot confidently takes proportional actions to avoid a full-blown airplane upset.

Recovery

The recovery side of upset training translates all of the academics into structured practice, be it the visualization of recovery procedures in the classroom, or repetitive skill practice in simulated and/or in flight settings. Recovery training involves developing timely, proportionate, and appropriate use of primary and/or alternate controls to effect recovery from impending and full-blown upset scenarios. Recovery skills are typically complex and perishable; therefore, not only is repetition is needed to establish the correct mental models, but recurrent practice/training may be necessary as well.

The context in which UPRT procedures are introduced and implemented is also an important consideration. The trainee must clearly understand, for example, whether a particular procedure has broad applicability, or is type-specific. To attain the highest levels of learning possible, the best approach usually starts with the broadest form of a given procedure, narrowing then to type-specific alternatives.

Applying Crew Resource Management and **Single Pilot Resource Management**

The concept of crew resource management (CRM) is introduced in the chapter on Aeronautical Decision-Making in the FAA Pilot's Handbook of Aeronautical Knowledge. CRM applies in the upset environment as well, even during single-pilot operations. When available, a coordinated crew response to potential and developing upsets can provide added benefits such as increased situational awareness, mutual support, and an improved margin of safety. Since an untrained crewmember can be the most unpredictable element in an upset scenario, initial UPRT for crewed operations should be mastered individually before being integrated into a multi-crew, CRM environment.

While the fundamental principles of CRM remain valid during an airplane upset, the time line may be intensely compressed; consequently, a crew must be able to accomplish the following:

- Communicate and confirm the situation clearly and concisely;
- Transfer control to the most situationally aware crewmember;
- Using standardized interactions, work as a team to enhance awareness, manage stress, and mitigate fear.

To the extent time and conditions permit, single-pilot operations can similarly benefit by tapping outside resources to assist with troubleshooting, diverting to an alternate landing site, and managing stress. Provided such resources are managed properly, bringing air traffic control, other pilots, or maintenance technicians into the equation may prevent a situation from culminating in a loss of control.

UPRT versus Aerobatics

Since the upset training and aerobatic training environments share a number of common attributes, the two are often—yet erroneously—equated. For example, both incorporate similar language: G-load, spins, rolls, high AOA, stalls in any attitude. At times, both may share the same equipment: aerobatic-capable aircraft, parachutes, waivered airspace. And both types of training certainly have their place, and indeed may be mutually beneficial. But the key distinction lies in the training objectives: the primary goal of upset training is to help pilots overcome sudden onsets of stress to avoid, prevent, and recover from unplanned excursions that could lead to LOC-I accidents in any aircraft type (from this standpoint, an aerobatic-capable aircraft is simply a proxy platform during UPRT); the main goal of aerobatic training, by contrast, is to teach pilots how to intentionally and precisely maneuver aerobatic-capable aircraft in three dimensions.

Also, the type of training platform used for upset training ultimately is less critical in the overall UPRT scheme, though as previously discussed, hands-on upset training in an aerobatic-capable aircraft represents the pinnacle of the UPRT experience.

Summary

According to the Introduction in the FAA Practical Test Standards, the baseline requirement for all pilots is the ability to maneuver an aircraft such that “the successful outcome of the flight is never in doubt.” This applies regardless of aircraft type or size. The foundation of aviation safety rests on a pilot’s ability to control an aircraft safely in any situation that could reasonably be encountered, to guide it clear of danger, and to provide for the safety of passengers and others. Pilots-in-command accept a heavy responsibility for the operation of their aircraft, including flying well within the limits of their and their aircraft’s abilities and avoiding preventable accidents. A commitment to recurrent training to maintain skills that may not be applied on a regular basis is every pilot’s duty.