# Pilot Response in Time Critical Aircraft Upset / Loss of Control Inflight (LOC-I) Events

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**Introduction.**

**Scenario 1.** You are the PIC of a twin engine aircraft during takeoff. Just after liftoff, you hear a very loud "bang," and the aircraft suddenly yaws and rolls to the right and rapidly begins losing airspeed. The response to this V1 cut/right engine failure on takeoff is memorized and trained to proficiency because of the time critical nature of the emergency. The cues are easily recognizable and predictable due to practice and repetition and the response is almost automatic. This is a familiar, well-rehearsed event that all multi-engine pilots are prepared to address.

Now let's pretend you are the PIC of that same aircraft but for some reason you have never had any training for an engine failure on takeoff. You are now experiencing this time critical emergency for the first time, on your own, with no qualified instructor in the aircraft. How well do you think you'll do? Do you think that your experience and background in all other aspects of basic pilot training will save you and the aircraft? Silly question, because that can't happen, right? That's not how we train.

Yet we treat upset training the same way as this "silly" imaginary scenario. With very few exceptions, we don't train for flight outside of the normal operating envelope as part of any required civil pilot training regimen. Pilots facing an airplane upset, or Loss of Control In-flight (LOC-I), situation are usually rapidly hurled out of the normal licensing flight envelope with no training to implement a time-critical response to a rapidly escalating emergency situation, much less, safely recover from the ensuing LOC-I. They are expected to build a response to these "worst case" scenarios *as they are happening*. The rapid rate of escalation of these time critical emergency situations and the associated human factors of startle, surprise and fear impede their cognitive and decision making abilities and slow the response time. Yet pilots facing an engine failure at the worst possible moment do just fine due to training which is commensurate to the task.

*"One faulty assumption by pilots is that their day-in, day-out expertise in the* [normal envelope] *will give them the skills, discipline and awareness necessary to prevent or recover from an airplane upset event."* [1]

To reinforce this point, the following scenario is an example of the aerodynamic predictability of a sideslip excursion out of the normal flight envelope—the same type experienced in the engine failure on takeoff scenario above. Yet the outcome is quite different.

**Scenario 2.** You are now the PIC of a large air transport category aircraft and are on approach when suddenly, the aircraft's rudder fails to the full right position and the aircraft suddenly yaws and rolls to the right. The nose also starts to drop due to the increased drag from the uncoordinated flight condition. What do you do?...still thinking?...too late. If you did not respond to this aerodynamically similar time critical emergency in the same way that you responded to the engine failure in Scenario 1, you and all your passengers are dead. This scenario did happen—most notably twice in the early to mid-1990s [2, 3] —and both aircraft and all aboard were lost. Yet, the aerodynamic condition of the engine failure on takeoff above and these hardover rudder accidents is exactly the same, a sideslip excursion out of the normal flight envelope. Though the causes are different, all of the aircraft in these scenarios yawed into a skidded flight condition.

So why were the pilots unable to respond appropriately and in a timely manner to the hardover rudder condition? Why were the pilots unable to correlate a similar escalating skidded flight condition seen in the V1 cut to the same aerodynamic condition in the hardover rudder scenarios? Both situations have the same cues. Both are predictable in that both can end up in an uncoordinated stall which will result in a dynamic uncommanded roll resulting in LOC-I. One situation is trained to proficiency to prevent LOC-I, and one was not (although procedures are now in place to address hardover rudder in the B737).

There are a myriad of LOC-I scenarios in various databases ranging from the yaw excursions discussed above to AOA excursions (stall), unusual attitudes in pitch and bank, structural integrity excursions (G and airspeed), and dynamic uncommanded roll and pitch excursions. The causes of these excursions are plentiful as well. They range from environmental (wake turbulence, icing, etc.) to systems anomalies (flight management systems automation, autopilot, flight control malfunctions/failures, etc.) to pilot induced (inattention, poor crosscheck, distraction, spatial disorientation, etc.). Wouldn't it be nice to have one response to all of them—trained to proficiency; a response that address extreme unusual attitudes, stalls, wake turbulence encounters, and more? Even better if the strategy could be used for both prevention and recovery…a lot less brain bytes needed for decisions in time critical situations …A strategy that could be easily accessed from the pilot's "clue bag" in very short order and then executed in seconds or less to prevent and if necessary recover from an aircraft out-of-control situation?

The strategy must be comprehensive and go beyond the current basic pilot training regimen and include in-depth aerodynamics and academics to address upset prevention causes and aircraft behavior in LOC-I situations. Training should also include on-aircraft training in certified all-attitude aircraft to replicate, as close as possible, life threatening upset/LOC-I situations that also address human factors issues (startle, surprise and fear) that impede pilot decision making and train pilots to focus on a memorized strategy to prevent and/or safely recover the aircraft. Finally, training in type-specific or similar aircraft simulators should be accomplished to exercise crew resource management (CRM) skills in time critical upset/LOC-I situations. This training regimen must also be administered by highly qualified upset prevention and recovery training (UPRT) instructors.

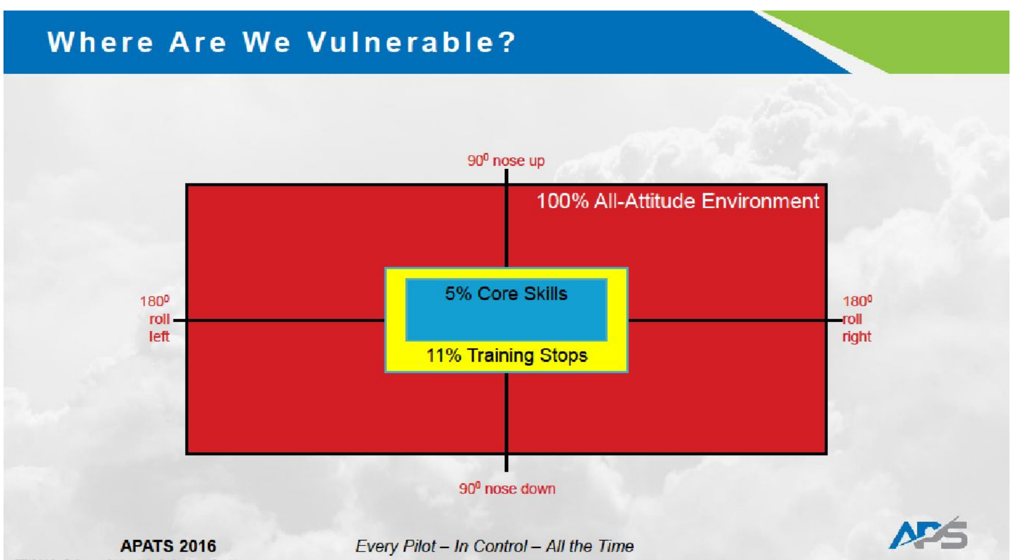
There has been a plethora of articles and studies that explain why basic flight training does not give pilots the skills, experience or proficiency to address these and many other upset/LOC-I scenarios. The mantra of maintaining aircraft control, analyzing the situation and taking appropriate action is unsuitable in upset/LOC-I situations. It is impossible to maintain aircraft control if the aircraft is out of control. The first priority should be to regain aircraft control, then worry about maintaining it. Then, and only then, should we worry about minimizing altitude loss or maintaining heading or wings level flight. There is also no time for an in-depth analysis of the situation. Time critical situations require preprogrammed training based on the predictability of the situation and must be based on cues to ensure an adequate response within the time available. The training regimen must also address the human factors associated with life threatening situations. It is interesting that as a course of normal pilot training, we don't train for upset/LOC-I situations. Yet, upset/LOC-I situations have the dubious distinction of being the number one killer of people and destroyer of aircraft across every venue of aviation worldwide. While the overall rate of upset/LOC-I accidents are low (approximately 9.3% in worldwide commercial operations as an example), 97% of commercial LOC-I accidents between 2010 and 2014 involved fatalities to passengers and/or flight crew and LOC-I accidents contributed to 49% of fatalities. [4]

**Purpose/Overview.**

This article will focus on the pilot in the cockpit and address aeronautical decision making (ADM) and the human factors impacts on the ADM process when confronted with time critical life threatening upset/LOC-I situations. We will reinforce the premise that an upset prevention and recovery strategy should and can be memorized and trained to proficiency just like any other time critical aircraft emergency because the aerodynamic and aircraft behavioral characteristics in upsets/LOC-I are predictable and therefore a response can be programmed. The training should include academic, on-aircraft and aircraft type-specific simulator training for best results in mitigating the upset/LOC-I threat to an acceptable level. From an operations risk management (ORM) and safety management system (SMS) perspective, this will include a look at the physical, physiological and psychological human factors impacts on the ADM process during an upset/LOC-I event and in particular, we will focus on how proper training to proficiency in responding to these situations can accelerate the ADM process resulting in a significant improvement in successful prevention and recovery within the time available. We will also look at success rates for pilots that have had proper training to address these situational human factors versus those that have not.

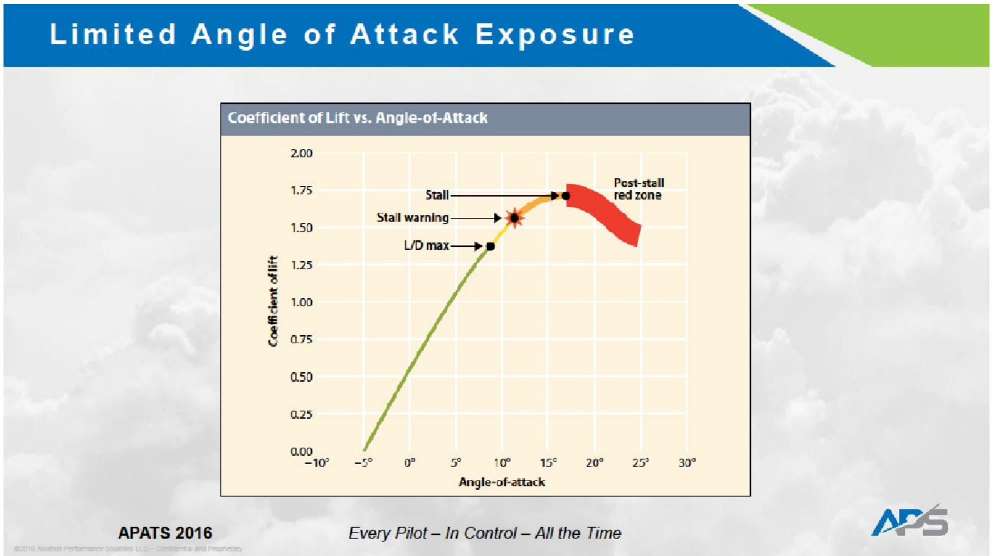
**Normal Flight Envelope.**

First we need to define the "normal" flight envelope addressed in pilot training. The FAA Commercial Pilot Airman Certification Standards (ACS) normal flight envelope is +/- 30° of pitch and +/- 60° angle of bank (AOB). This envelope encompasses only 11.1% of the total flight envelope (180° AOB and +/- 90° of pitch.) In addition, the Airplane Upset Recovery Training Aid, Revision 2 (2008) defines the boundaries between normal flight attitudes and the upset flight envelope as +/- 45° AOB and +25° degrees and -10° of pitch. [9] This envelope encompasses only 4.9% of the total flight envelope. [1] So what happens when you suddenly find yourself in the other 89-95% of the flight envelope? Maybe inverted …and possibly in a full stall. There is a faulty assumption across the aviation training world that expertise in the normal flight envelope somehow gives pilots skills, discipline and awareness to prevent or recover from an airplane upset in the other 89-95% of the flight envelope.




*"One faulty assumption by pilots is that their day-in, day-out expertise in the blue region will give them the skills, discipline and awareness necessary to prevent or recover from an airplane upset event. An upset event that is rapidly hurtling out of the blue region, through the yellow region and into the last region we call the all-attitude red zone can present unexpected, unfamiliar and sometimes violent*

*situations that can rapidly degrade a pilot's ability to prevent the escalating LOC-I condition or to effectively recover…The obsolete paradigm of minimizing altitude loss has generated situations in which pilots continued to pull back on the control column, further increasing AOA in the stall and immersing themselves in the red zone…. These challenges may never have been experienced, and pilots have not been consistently trained on how to exit from this deadly region…The risk of a fatal accident increases in proportion to duration and depth of exposure to the red zones."* [1]



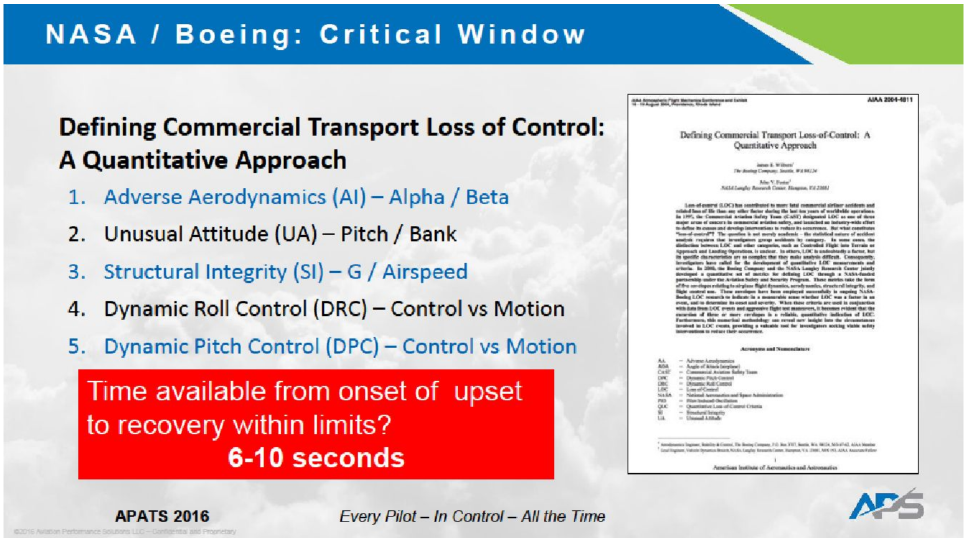

**Framing the Issue.**

In their 2004 paper, *"Defining Commercial Transport Loss-of-Control: A Quantitative Approach,"* James E. Wilborn and John V. Foster researched six commercial accidents to qualify and quantify criteria for a LOC-I event. They developed a set of metrics for defining LOC-I. Collectively known as the Quantitative Loss-of-Control Criteria (QLC):

*"Generally, LOC is described as motion that is:*

- *Outside the normal operating flight envelopes*
- *Not predictably altered by pilot control inputs*
- *Characterized by nonlinear effects, such as kinematic/inertial coupling, disproportionately large responses to small state variable changes, or oscillatory/divergent behavior*
- *Likely to result in high angular rates and displacements*
- *Characterized by the inability to maintain heading, altitude, and wings-level flight"*

The QLC are composed of five envelopes that capture the most important relationships between these parameters. "*… if a maneuver crosses three or more envelopes, it will be classified …as "out of control." …In rare instances, a maneuver can depart unexpectedly and exceed four or all five of the QLC envelopes."* [5]




It is important to note that as part of their analysis of six commercial aircraft LOC-I accidents, *"in all but one case, the* (LOC-I) *situation progressed from an initial upset to a state of lost control in less than 10 seconds."* [6] This "critical window" where the aircraft transitions from controlled flight to a complete loss of control is a busy time where many things are going on in the cockpit and particularly with the pilot(s).

Without an industry standard definition of the difference between time favorable and time critical ADM, we will use the above critical window definition of 6-10 seconds as an arbitrary delineation between the two for the purposes of this discussion.

The important takeaway from this information is that Wilborn and Foster define general predictability of aerodynamic and aircraft behavior characteristics in upset/LOC-I events. Armed with this information, we should be able to build a programmed response to these events with a prioritized set of steps. In doing so, we should be able to pre-program a training regimen to shortcut/accelerate the ADM process in order to appropriately and proportionally respond within the critical window defined above. This strategy must rely on defined cues for an upset/LOC-I event while simultaneously suppressing interference by human factors with the ADM process through repetitive training to proficiency.

**Risk Elements.**

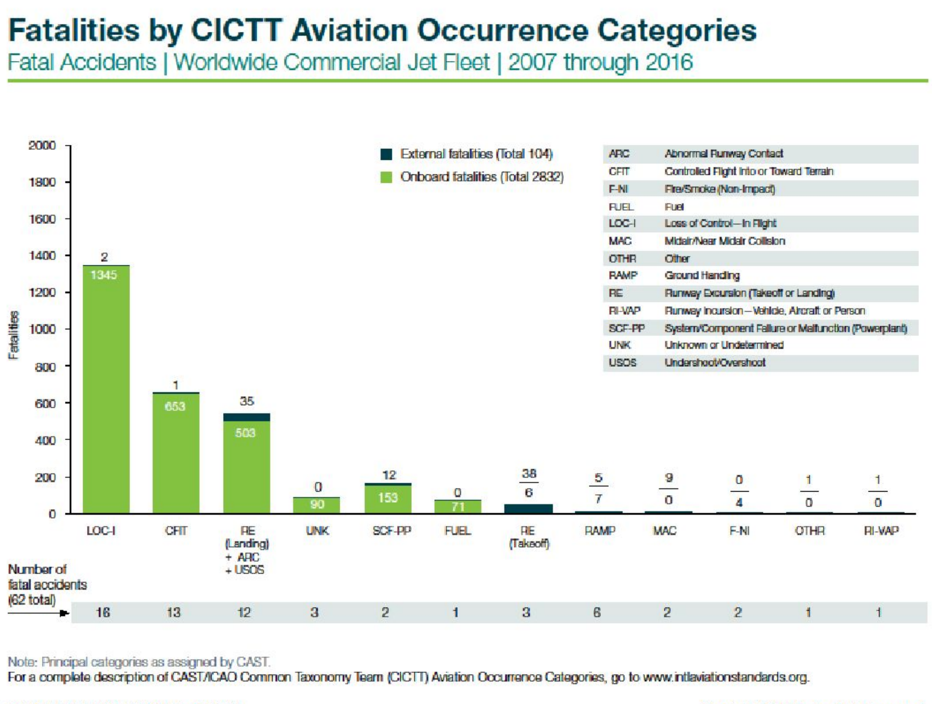
FAA Advisory Circular (AC) 60-22 describes four risk elements in the ADM process (pilot, aircraft, environment, operation). [7] The strategy we train for and which we employ in response to upset/LOC-I events must also address all four of these risk elements. The operation and the environment risk elements are not mutable in a time critical situation and although they would be addressed in training, it is beyond the scope of this article to address them in detail. Although rare, aircraft automation and flight controls fail. Therefore, in an actual upset/LOC-I event critical window, it is the pilot, as the last line of defense that makes the difference between a successful intervention to prevent or, if necessary, recover. If the pilot is inadequately prepared for these time critical situations, a hesitation, delay or wrong decision may make the situation non-recoverable. Decisions must be made by the pilot in a timely and controlled manner by pre-training to proficiency. Basic skills that are trained in the normal flight envelope are not necessarily appropriate and/or sufficient to consistently and safely prevent or recover from LOC-I situations. As an example, in a full stall or at high speed, there is a potential for ailerons to work backwards! [15, 16]

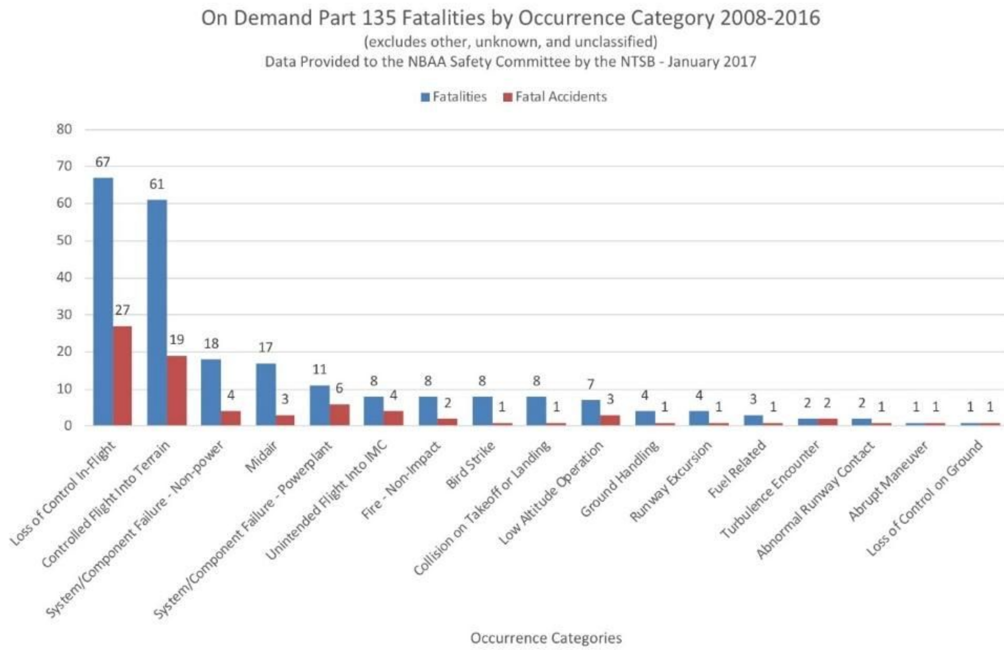
*"As the time frame for stall/upset response compresses, onto the scale of seconds or fractions of a second, the pilot's challenges become quite different from time-favorable ADM…When startled by a rapid-onset upset event, implementing the correct, time-sensitive control inputs is often the most difficult aspect of prevention… pilots tend to over-react to rapid onset upset situations…Pilots in real upsets have been observed making the situation worse, sometimes unrecoverable. As the situation transitions from prevention to recovery…The pilot must take immediate corrective action."* [3]

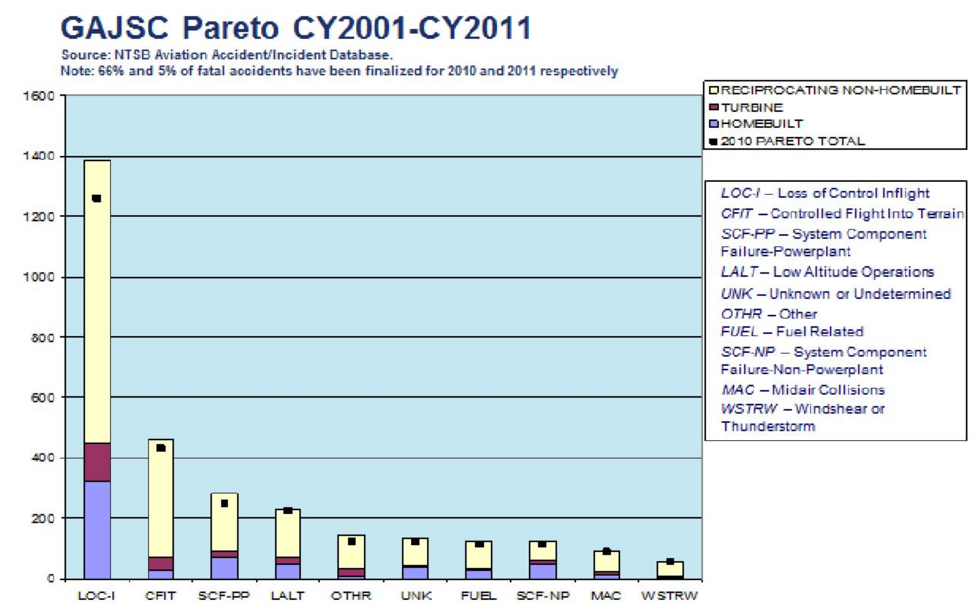
**The Threat.**

Below, you will find the *Statistical Summary of Commercial Jet Airplane Accidents Worldwide Operations, 1959 – 2016* (Aviation Safety, Boeing Commercial Airplanes, July, 2017). Between 2001 and 2016, LOC-I aircraft accidents were the leading cause of fatalities in commercial aviation. According to ICAO, LOC-I accidents represented only 3% of all accidents in 2015, but 33% percent of fatal accidents. You will also find the On-Demand Part 135 Fatalities by Occurrence statistics from 2008-2016 and the NTSB's General Aviation accident statistics from the 29 October 2014 General Aviation Joint Steering Committee (GAJSC) Final Report of the Loss of Control Working Groups that tell the same story.

Further drill-down of the information and causes of the individual LOC-I accidents reveal that they occur in all operations and environments and that in certain cases, the automation designed to mitigate this threat failed and/or there was a flight control (or other) malfunction/failure. Lastly, in many cases, there was also pilot error involved. As mentioned earlier, when all else fails, it is the pilot that must be properly trained and prepared to be the last line of defense in avoiding disaster. It is clear that pilot training is one of the major issues that must be addressed to mitigate the LOC-I threat to an acceptable level.






**Upset/LOC-I Training Gap.**

To reinforce the training gap issue, in a formal investigation conducted in 2007-2008, 115 pilots of varying experience levels participated in UPRT at Aviation Performance Solutions and were evaluated for their capability to effectively respond to the following five flight conditions:

1. Nose Low Over-bank with approximately 120° angle of bank and 30° nose low pitch.
2. Wake Turbulence aggravated by rapid onset entry to generate startle response.
3. Cross-Control Stall which included ample, but unheeded, prevention opportunities.
4. Nose High Unusual Attitude of more than 45° nose high and 10 knots above stall speed.
5. Control Failure: Rudder Hard Over which simulates 80% deflection and jam.

The results of the study assessing pilot capability and training program effectiveness with regard to the measured tasks are displayed below.

| | **Effective Pilot Response to Potential LOC-I Conditions** | Assessed on: |
|---|---|---|
| **Before Training** | **28.10%** | 1st flight |
| **After Training** | **96.30%** | 5th flight |
| | | |
| Pilots evaluated | 115 | |

The contention by many that there is no need for specific UPRT training is not supported by the accident statistics or the above survey. The results of this study extrapolated to the total pilot community portend that pilots that have been trained in the normal flight envelope but who have not received comprehensive all-attitude UPRT training, will suffer a 72% failure rate when confronted with a real world upset/LOC-I event. Without changes in mandatory training based on aligning pilot performance capabilities with the actual threat represented by the accident record, a significant reduction in the current LOC-I accident rate is not likely to be achieved. [8]

To properly address the threat and knowing there is, as yet, no foolproof engineering solution to do so, there is ample evidence to support the supposition that comprehensive UPRT training to bring pilot competency and proficiency to a level that positively mitigates the upset/LOC-I threat to an "acceptable" level requires a three-pronged approach of specialized training and resources to include (i) comprehensive academics, (ii) on-aircraft training with certified UPRT instructors, certified all-attitude aircraft, and (iii) aircraft simulators capable of high fidelity replication of the entire flight envelope, to include stalls. In addition, the training can be even more effective if we understand how human factors impact pilot ADM capabilities in time critical upset/LOC-I situations and why a memorized prevention and recovery strategy comprehensively trained to proficiency is the best solution to address this issue. In fact, two of the three legs of this "Triad of Training" (academics and on-aircraft training) had immediate and significant positive impact on reducing the upset/LOC-I threat in the above survey (the survey pilots had only with a 28.1% success rate pre-training and 96.3% success rate post-training). Two years after the survey, the success rate of these pilots (pre-recurrency training) was 88%. This reinforces the need for periodic UPRT recurrent training (APS-recommended every two years).

**Upset/LOC-I Training Strategy: Aerodynamics Predictability and Response Programmability.**

The 1979 Air Force Office of Scientific Research "Aircraft Emergency Decisions: Cognitive and Situational Variables" study describes an approach to the application of theoretical models in the development of training requirements. The study is relevant to decision making and cognitive behavior in emergency situations (to include upset/LOC-I).

The study determined that in certain events, behavior of the malfunction (or, for upsets/LOC-I, aerodynamics and general aircraft behavior) and outcomes are predictable. In general, their cues are well-defined, recognizable, have high diagnosticity and reliability. Boldface (memorized)-like training appears to be a relevant pilot response in these cases. These emergencies involve straightforward relationships between cues and malfunctions, information processing requirements are low, and pilot response procedures are known and programmable. This conceptualization makes it possible to deal with the notion of "templates" in the ADM process, their role in training and in actual emergencies, and their limitations. Templates may be defined as preplanned responses to emergencies. Programmable behavior is characteristic of the actions prescribed by Boldface procedures in that entire sequences of actions can be specified and trained in advance of the emergency. Programmed behavior typically does not include complex cognitive components.

This concept is very applicable to upset/LOC-I training. Wilborn and Foster describe the QLC which are composed of five defined envelopes that capture the most important relationships that define a LOC-I event. Combined with the fact that aerodynamics and aircraft behavioral characteristics during QLC excursions from normal flight to upsets to LOC-I events are predictable, a possible general single memorized response can be formulated, trained and implemented to address a myriad of upset/LOC-I situations. This trained pilot response would generally apply to all aircraft, operations and environments and apply to all venues of aviation worldwide. Specific exceptions could (and should) be made if necessary based on type specific aircraft aerodynamic and behavioral characteristics differences. The goal would be for the pilots to recognize the QLC excursion cues in time critical situations in all operations and environments and implement the response strategy before an upset becomes a LOC-I event by exceeding three or more of the QLC envelopes.

In looking at the engine failure scenario above, pilots are trained to proficiency to recognize cues based on the sideslip excursion (envelope #1) and implement a response strategy or procedure before exceeding an additional two or more QLC envelopes. They are able to prevent a LOC-I and regain and maintain aircraft control through a memorized, trained to proficiency response based on the predictability of the aerodynamic and aircraft behavioral characteristics during an engine failure on takeoff situation. In the hardover rudder scenario(s), the pilots were not trained nor did they recognize the cues of this aerodynamically similar sideslip excursion and did not respond in an appropriate or timely manner. The startle, surprise and fear human factors then impeded their ADM abilities. The result was an uncoordinated stall (envelope #2) with a resultant dynamic uncommanded roll excursion (envelope #3). The aircraft in the two hardover rudder scenarios were now out of control and the altitude available was less than the altitude required to effect a safe recovery.

So, what are the prioritized steps in the strategy to adequately address QLC envelope excursions and prevent or recover from an upset/LOC-I event? Industry and APS agree that the first priority is to address the adverse aerodynamics (AI) QLC envelope of AOA (alpha) and sideslip (beta). This first step to unload the aircraft in an upset/LOC-I event mitigates the dangers of stall and the associated characteristics (buffet, lack of roll control, lack of pitch authority and an inability to arrest descent rate [10]), which by definition is a LOC-I. Reducing AOA also reduces induced drag which makes power more effective (critical in high altitude situations), it increases roll effectiveness, it reduces stall speed (less than 1G), and it helps minimize altitude loss in overbanked situations.

Canceling sideslip, or if unable, transitioning the aircraft from a skidded flight condition to a slip helps mitigate the risk of an uncoordinated stall with a resulting dynamic uncommanded roll excursion. The next two steps in this four step strategy are interchangeable depending on situation and/or type-specific aircraft behavioral characteristics. The baseline strategy addresses roll and then power, whereas a variant strategy addresses power and then roll. The last step in the strategy is to stabilize the aircraft, signaling a regain of control and as situational awareness increases and time criticality decreases, the pilot can return the aircraft to the "normal" flight envelope. Properly trained to proficiency, a proportional and appropriate application of this strategy in an upset/LOC-I event should adequately mitigate excursions in the QLC envelope and allow pilots to safely regain and maintain aircraft control.

In addition, criticality, with respect to behavior, refers to the amount of time available to perform an action…High time-criticality refers to situations in which only a few seconds are available to make a decision or take an action (6-10 seconds for the purposes of this article based on the aforementioned critical window):

*"…The entire pattern of cues must be trained so thoroughly that the correct responses to it are immediate. In some cases, there may be some fuzzy boundaries between two or more cue patterns, so that some training in problem recognition and structuring will be required to deal with malfunctions belonging to these time critical situations. When this is the case, very little decision-making is necessary at the time the malfunction is diagnosed; at the most, some problem recognition and structuring may be required."* [11]

**Human Factors: Stress Effect on ADM.**

An aircraft emergency can combine the physiological effects of a harsh physical environment with the requirement for rapid, complex decision making under conditions of uncertain information and high personal risk. It would appear, based on the Air Force study that aircraft emergencies are among the ultimate stressors for flying personnel.

"… *the element of threat or personal risk is the critical factor that underlies the human operator's decision errors that are involved in some aircraft…a pilot's reaction to the threat of an impending disaster may well account for more variance in performance among pilots… than their susceptibility to all the physical and physiological stressors combined…Human behavior in response to extreme factors may be characterized by (i) a sharp increase in excitability expressed in impulsive acts, impairment and loss of skills or (ii) inhibition and even the cessation of activity. Both types of reactions result in a disorganization of rational activity on the part of the individual…Adequate mission performance requires more than just the requisite mechanical skills. Resistance to the disorganizing effects of stress must be sufficient to permit the mechanical skills to operate in an effective, integrated fashion.* [12]

This cessation of activity due to life threatening stress is also described as "Freezing Behavior" and "*can be accounted for by considering the temporal constraints on cognitive information processing in a rapidly unfolding, real-time environment. 1.) If an appropriate response to such an event has been prepared and embedded in the cognitive database of behavioral schemata, then the speed of response can be as fast as 100 milliseconds…. 2.) If more than one possible response is available, then choosing the correct behavioral* [response] *sequence requires simple decision making, which can take 1–2 seconds. 3.) If no appropriate response exists in the person's database, then a temporary behavioral schema has to be created. This will take at least **8–10 seconds under optimal circumstances and much longer under threat."*** [11] This exceeds the 6-10 second LOC-I critical window described above and therefore for pilots with no UPRT training or exposure to flight outside of the normal flight envelope, the time required to construct and execute an upset/LOC-I prevention/recovery strategy with no prior training/exposure is less than the time available…discounting a "lucky guess."

*"…The result is that no behavioral schema will be triggered from the schemata database and no temporary schema can be created within the time available. This produces a cognitively induced paralysis or 'freezing' behavior. The clear implication is the importance of training…. At the intuitive level this seems obvious… What is only now becoming apparent is the manner in which training works; namely, by providing the temporal and working memory capacity necessary to create a temporary schema of actions, to assemble those actions into the correct sequence, and then to combine those actions into a composed whole, thus reducing cognitive storage and processing demands. Once this process has been completed, an environmental danger signal* (cue) *can trigger the appropriate composed response…Clearly, lives could be saved if these principles could be applied…"* [11]

In addition, *"because anxious thoughts tend to preempt working memory's limited storage capacity, the individual may have difficulty performing computations that would normally be easy and have difficulty making sense of the overall situation and updating the mental model of the situation (i.e., situation awareness)."* [12]

This presupposes that as a LOC-I situation escalates, there is a corresponding loss of situational awareness, particularly for an untrained pilot.

*"To understand how stress affects the skilled performance of pilots, especially in emergencies (which by their nature involve novelty, uncertainty, and threat), one must understand the distinction between automated performance of highly practiced tasks and effortful performance of less familiar tasks that draws heavily on attention and working memory. If the threat produces anxiety, pilots' performance is likely to be undermined in specific ways... Fortunately, with highly practiced tasks, our dependence on these two limited resources diminishes considerably, performance becomes largely automatic, and we can perform these practiced tasks with minimum attention and effort."* [14]

These concepts are supported by the aforementioned Air Force study in that from a training standpoint, in order to implement a highly effective UPRT program, *"it is argued that the subject must cognitively perceive the situation as stressful, so that* [they] *may react realistically and not "as if." Simulation of a stressful environment, then, must avoid cues which invite the subject to deliberately assume a role or which provide* [them] *with more psychological support or sustenance than* [they] *will receive in the reality to which the findings must generalize. Furthermore, the task* [they are] *to perform must be meaningful in the stress-producing context. Stressors which fulfill these requirements ought to produce (1) a measurable disturbance of performance, (2) a report of awareness of a feeling of discomfort, fear, threat, or unpleasantness, and (3) a measurable perturbation of physiological (homeostatic) processes."* [13]

The information presented in this article (and many more) should lead to the conclusion that the aviation community needs a comprehensive, best practice training regimen to address upset/LOC-I. The training should be a campaign that addresses time critical ADM from a knowledge, human factors, skills, strategy and procedures perspective which results in an upset/LOC-I response strategy that is easily accessed and quickly executed in time critical situations to prevent an upset from progressing to a LOC-I event. The strategy is even better if it can be used for both prevention and recovery. It is the best way, given current technologies, to "fine tune" the last defense in an upset/LOC-I situation – the pilot. The objective of this campaign is to mitigate the LOC-I threat to an acceptable level.

What all this means from a training standpoint is that to comprehensively address UPRT and satisfactorily mitigate the upset/LOC-I threat, UPRT training programs should be administered by highly qualified UPRT instructors and the training regimen should include:

1. **Specialized UPRT academics** that cover aerodynamics to solidify the concept that upset/LOC-I aerodynamic and aircraft behavioral characteristics are predictable and therefore a response can be programmed. Academics should also provide contextual and cognitive understanding of the upset/LOC-I cues, human factors (particularly startle, surprise and fear) that interrupt, delay and possibly freeze the ADM process in time critical, life threatening situations. Provide the trainee understanding that due to human factors and the time and safety criticality of upset/LOC-I events, the prevention/recovery strategy must be memorized and trained to proficiency through repetition with the goal of accelerating the ADM response to "beat the clock" with reference to the time critical window of 6-10 seconds.

2. **On-aircraft training** in an all-attitude certified aircraft to train the recovery strategy to proficiency and build a confidence level of the predictability of aerodynamics and aircraft behavioral characteristics in all attitude upset/LOC-I flight situations. This type of training must also replicate, as close as possible, the life threatening physiological, physical and psychological impacts of time critical and/or escalating LOC-I events and allow the trainee to understand the need to suppress this "shock and awe" of sensory overload and focus on accomplishing the strategy in a timely, professional, proportional and disciplined manner.

3. **Aircraft simulator training** to apply UPRT strategy in a familiar (perhaps aircraft-specific) environment that emphasizes CRM in a crewed environment and educates pilots on the limitations of their aircraft-specific performance responses. This training needs to be tempered based on simulator fidelity in the all attitude flight environment and particularly when addressing stall characteristics.

**Conclusion.** It is important to note that *"presently, the required magnitude, quality and relevance of startle factor training for UPRT cannot be fully accomplished exclusively through ground-based simulation. Appropriate UPRT training in all-attitude, aerobatic-capable airplanes readily immerses the trainee in dynamic surprise/startle and fear experiences that are recognized in scientific research as unique and necessary."* No single training medium on its own comprehensively reduces the risk of the Loss of Control In-flight (LOC-I) threat. Effective LOC-I mitigation necessarily integrates focused academics with multiple on-airplane training sessions to embed foundational skills. Jet pilots must transfer these core skills to their aircraft via state of the art flight simulation. This "triad of training" promotes synergistic learning resulting in a powerful, hands-on experience with lasting impact and satisfies the requirements for time critical pilot ADM in aircraft upset/LOC-I situations. It gives pilots the best chance for success. [3]

## Definitions

Terms defined from the International Civil Aviation Organization (ICAO) Doc 10011, Manual on Aeroplane Upset Prevention and Recovery Training:

**Startle.** The initial short-term, involuntary physiological and cognitive reactions to an unexpected event that commence the normal human stress response.

**Stress (response).** The response to a threatening event that includes physiological, psychological and cognitive effects. These effects may range from positive to negative and can either enhance or degrade performance.

**Surprise.** The emotionally-based recognition of a difference in what was expected and what is actual.

**Threat.** Events or errors that occur beyond the influence of the flight crew, increase operational complexity and must be managed to maintain the margin of safety.

**Threat management.** The process of detecting and responding to threats with countermeasures that reduce or eliminate the consequences of threats and mitigate the probability of errors or undesired aeroplane states.

**Train to proficiency.** Approved training designed to achieve end-state performance objectives, providing sufficient assurances that the trained individual is capable to consistently carry out specific tasks safely and effectively.

**Other pertinent definitions.**

**Situational Awareness**. "*A pilot's continuous perception of self and aircraft in relation to the dynamic environment of flight, threats, and mission, and the ability to forecast, then execute tasks based on that perception.*" [4] FAA AC 60-22 defines situational awareness as *"…the accurate perception and understanding of all the factors and conditions within the four fundamental risk elements* (pilot, aircraft, environment and operation) *that affect safety before, during, and after the flight."* [5]

**Cue.** A cue is any manifestation in the pilot's environment that is unexpected and that is perceived through any of the senses. Cues are conceptualized as patterns of information that are described in terms of a set of attributes. The interpretation of cues is not only a function of training but also of general and specific experiences with the aircraft. [9]

**Stress.** Stress is the body's non-specific response to demands placed on it *(internal / external). Stress* changes physiological / psychological patterns and forces the pilot to adapt. Stress therefore affects the decision-making process. The introduction of variables commonly recognized as extreme Stressors will result in performance decrement or impairment in the decision-making process. [10]

**Templates**. Templates may be defined as preplanned responses to emergencies. A template is a special case of a representational system, which can only be activated when the pattern of the environmental stimuli matches all the elements in the system. It is extremely well-rehearsed and rigid in the sense that individual external elements are not likely to activate other systems. In other words, the correspondence between external events and the elements of the template is highly specific, and the system itself is relatively autonomous and generally it can be activated only by a specified configuration of external stimuli. In this way, responses to these external stimuli are highly reliable and stress-resistant. [11]

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2. United Airlines Flight 585 was a scheduled passenger flight on March 3, 1991 from Denver to Colorado Springs, Colorado, carrying 20 passengers and 5 crew members on board. The plane experienced a rudder hardover while on final approach to runway 35 at Colorado Springs Municipal Airport, causing the plane to roll over and enter an uncontrolled dive. There were no survivors.

3. USAir Flight 427 was a scheduled flight from Chicago's O'Hare International Airport to Pittsburgh International Airport, with a final destination of West Palm Beach, Florida. On Thursday, September 8, 1994, the Boeing 737 flying this route crashed while approaching runway 28R of Pittsburgh International Airport, Pennsylvania.. After the longest investigation in the history of the National Transportation Safety Board (NTSB), it was determined that the probable cause was that the aircraft's rudder malfunctioned and went hard-over in a direction opposite to that commanded by the pilots, causing the plane to enter an aerodynamic stall from which the pilots were unable to recover. All 132 people on board the aircraft were killed.

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