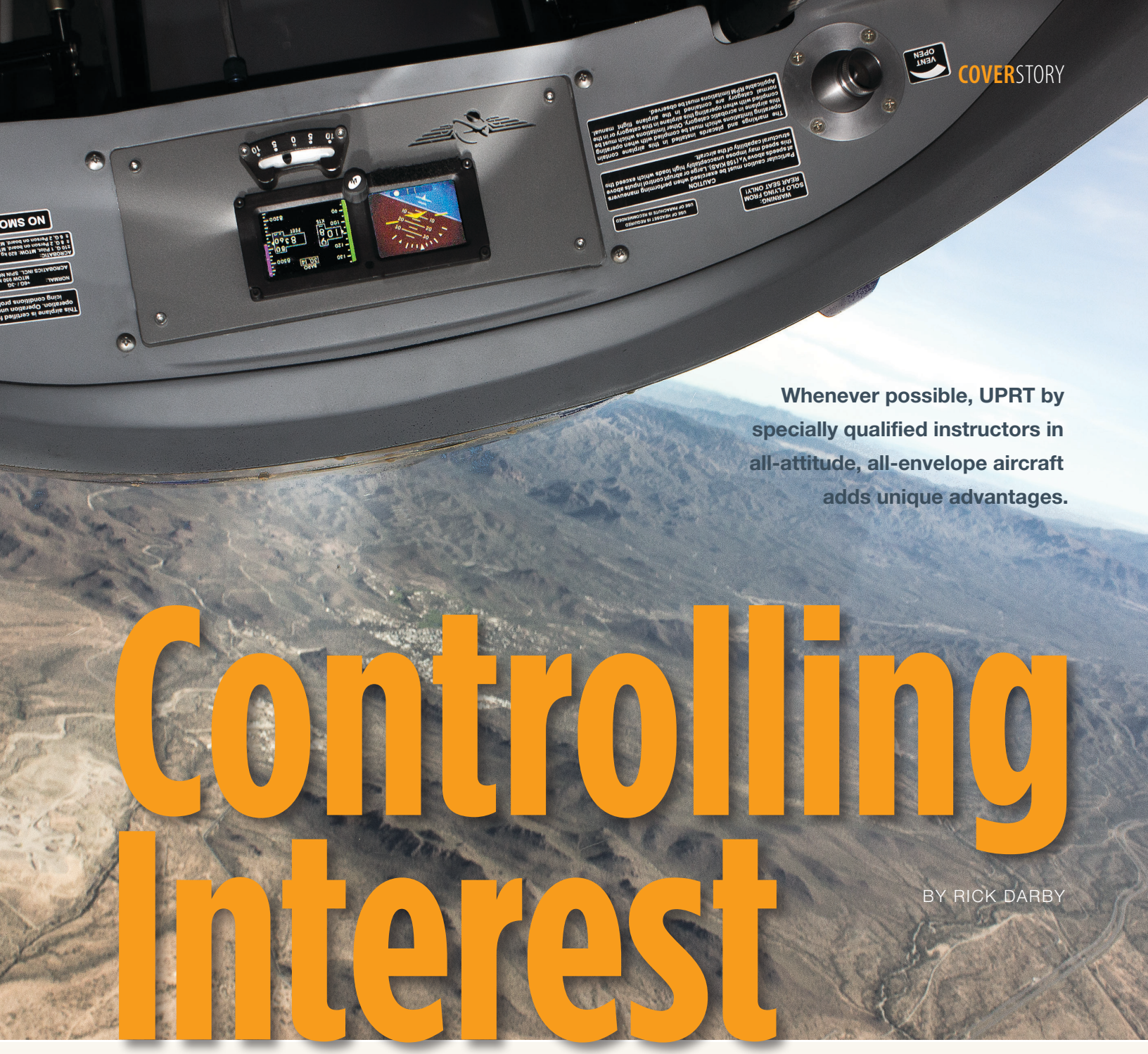


Whenever possible, UPRT by specially qualified instructors in all-attitude, all-envelope aircraft adds unique advantages.

Controlling Interest

BY RICK DARBY

Reducing the risk of loss of control–in flight (LOC-I) accidents, the leading cause of fatalities in commercial aviation between 2001 and 2011,[1] remains a priority of the International Civil Aviation Organization (ICAO) and the entire aviation community. As one of several steps to standardize and harmonize upset prevention and recovery training (UPRT), ICAO most recently has published Doc 10011, *Manual on Aeroplane Upset Prevention and Recovery Training*.[2]

Previous *ASW* articles have reported on ICAO's mid-2013 decision to update its existing standard to require *prevention* as well as *recovery* elements when UPRT is delivered for the multi-crew pilot license (MPL) and to make on-aircraft training of pilots at the commercial pilot licensing level (*ASW*, 7/13, p. 27) a recommended practice rather than a standard.

For multi-crew aircraft in air transport, however, the latest standard requires that the "applicant shall have, for the issue of an airplane

category type rating, received upset prevention and recovery training." A recent *ASW* article also detailed the role that near-term advances in flight simulation are expected to have in UPRT *(ASW,* 3/14, p. 28).

To re-emphasize the on-aircraft element of UPRT last covered in *ASW* three years ago, representatives of the Upset Prevention & Recovery Training Association (UPRTA),[3] which contributed expertise during development of the *Manual,* provided *ASW* with a new report that explains and encourages voluntary adoption of the on-aircraft element of UPRT whenever possible in light of ICAO's recommended practice.

In this paper, titled "Addressing On-Airplane Upset Prevention & Recovery Training: Primary Considerations for the Safe and Effective Delivery of UPRT,"[4,5] authors Randy Brooks, Paul "BJ" Ransbury and Rich Stowell[6] assert that, ideally, UPRT must culminate in "a structured experience throughout the flight envelope and stall/spin upset red zones."

They note that the *Manual* defines an airplane upset as "an in-flight condition by which an airplane unintentionally exceeds the parameters normally experienced in normal line operations or training. An upset is generally recognized as a condition of flight during which the pitch of the airplane unintentionally exceeds either 25 degrees nose up or 10 degrees nose down; or a bank angle exceeding 45 degrees; or flight within the aforementioned parameters but at inappropriate airspeeds."

The paper stresses that there is no substitute for actual airplane handling experience during training involving bank angles beyond 45 degrees, conducted in gradual stages increasing to 180 degrees, as well as high angles-of-attack, that will lead to a full aerodynamic stall-and-spin departure from controlled flight. Such extreme bank angles and angles-of-attack are limited to specific airplane categories, to be discussed later.

Prevention of negative transfer of training to transport airplane operation requires that recovery be taught and supervised by specially qualified UPRT instructors, not typical certificated flight instructors and maybe not even traditional aerobatic instructors, because most lack the essential background in demonstration and recovery from severe upsets.

To put their perspective in context, it helps to zoom out to view the whole scope of UPRT. "UPRT resources are divided into two training tracks: academic and practical," Brooks, Ransbury and Stowell say. "Practical training is further subdivided into two parts: on-airplane and flight simulation training device (FSTD). …

"The framework of academics, on-airplane and FSTDs, coupled with consistency of language, concepts, techniques and application across all stages, will provide pilots with the strongest and most enduring learning experience possible. Cementing the training to maximize the stated goals of UPRT, however, will require pilots to have an adrenalized, on-airplane experience.

"It is the on-airplane experience where academics become reality; where techniques practiced in FSTDs can be applied under real-time constraints and with more accurate aerodynamic behavior; and where pilot stress levels can be manipulated to levels comparable to those of real-life upsets, but in a controlled environment where skill sets can be perfected, bonds to mental models for recovery strengthened and confidence gained."

Adrenaline is a hormone secreted by the adrenal glands under conditions of high stress or excitement. It boosts the body's energy level so it can act quickly and decisively, increasing blood flow to the muscles and oxygen to the lungs, the paper says. Increased physical energy *per se* is irrelevant to responding correctly to conditions where LOC-I is a real threat, but they cite scientific evidence that an "adrenalized experience" or "adrenalized training" has a tendency to enhance learning and retention.[7,8]

The retention aspect is important. "Experiences acquired during the early stages of a pilot's development shape that pilot's approach to operating airplanes, and equally important, … the lessons learned are perishable," the paper says. "The application of upset prevention and recovery skill sets, therefore, not only needs to be reinforced continually throughout a pilot's career, but also needs to be framed continually within the proper context."

Given the strong influence of adrenalized learning on the UPRT experiences of pilots that the authors have observed — and potentially on the prevention of LOC-I accidents — the paper describes three core issues concerning the value of the on-airplane phase:

- "On-airplane training considerations;
- "Airplane and equipment considerations; and,
- "Instructor considerations."

Mind the Gaps

One ICAO document they cited states that "current FSTDs have limitations that render them incapable of providing the complete exposure to conditions synonymous with preventing or recovering from [an] LOC-I event…. These areas of missing experience provide gaps in pilots' understanding and proficiency when confronted with an actual upset."

The authors say that, "consequently, on-airplane UPRT is seen as necessary to fill the gaps. ICAO further acknowledges that on-airplane training provides experience and confidence in the

psychophysiological domain of upsets that cannot be fully realized in FSTDs alone."

On-airplane UPRT pushes pilots beyond their comfort zone, they say. Human factors in a developing or actual upset can include startle factor, disorientation, overreaction, fixation and cognitive bias.

Maximizing the positive effects of adrenalized learning can be realized under five conditions, they say:

- "Training is delivered in a consistent and regimented manner across all stages;
- "Trainees are exposed to the full range of roll and angle-of-attack envelopes;
- "Trainees are confident they can learn UPRT skills quickly;
- "Trainees see that UPRT techniques work, and experience them personally; and,
- "Trainees have a positive training experience."

Pitch and Bank Envelopes

Per the *Manual*, specific pitch and bank parameters define an airplane upset (Figure 1). In Figure 1, the green rectangle represents the normal flight envelope in which airline pilots operate. The yellow rectangle represents limits that, when exceeded, pilots are meant to cope with as part of commercial pilot training. The much larger red area shows the full dimensions of the UPRT envelope, which can involve essentially any combination of pitch and bank. Ideally, an airplane should never enter the red zone, and UPRT training is designed to prevent that from happening or, if it does, to prepare the pilot to immediately recognize the excursion and to regain control without delay.

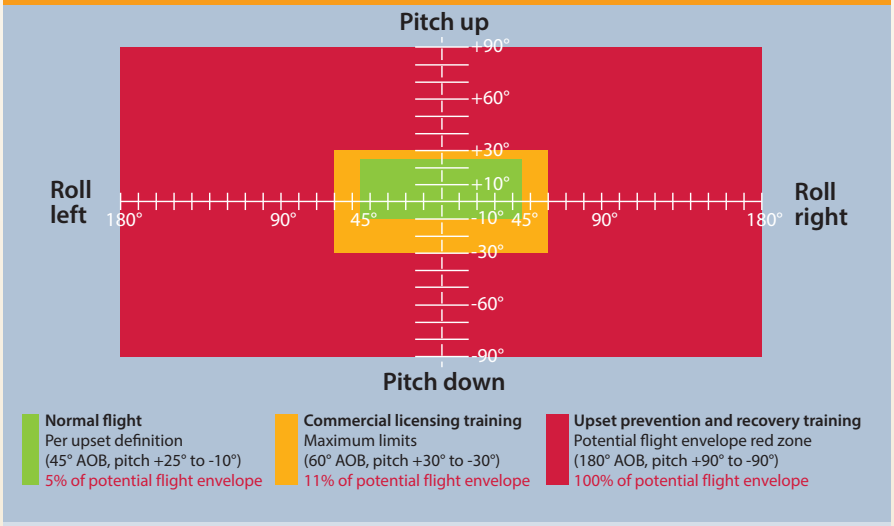
Incomplete exposure to the red zone leaves a pilot at a disadvantage should he or she ever have to recover from a severe upset, Brooks, Ransbury and Stowell say. "This does not at all suggest that pilots must only be exposed to 180 degrees of bank; escalation and recovery from the UPRT red zone can — and indeed should be — progressive," they say. "For instance, trainees might be exposed to escalating bank angles with roll recovery techniques applied at the following increments: 60 degrees, 90 degrees, 135 degrees, and ultimately, 180 degrees. This approach offers several key benefits, including:

- "Experiencing red-zone excursions coupled with appropriate mitigation strategies, initially while at lower angles of bank and reduced levels of stress;
- "Reinforcing the concept of prevention and the critical importance of bridging the gap between escalation and recovery paths with prompt, effective action (i.e., roll recovery techniques in this case); [and,]
- "Instilling the notion that intervention [action] must be taken regardless of the upset bank angle, rather than at some artificially set point on the escalation path."

Mitigation bridges are specific techniques appropriate to particular situations, the paper says. They help establish a mindset in which a pilot does not wait [for] a particular critical condition before beginning a recovery procedure, but instead reacts as soon as possible (Figure 2, p. 21).

The paper provides an example of how a mitigation bridge works: "As it pertains to recoveries from upset bank angles, 'push-then-roll' is an important UPRT technique … not only in terms of the sequence of the inputs, but also in terms of their magnitudes. 'Push' beneficially reduces angle-of-attack and g-load [a positive/negative multiple of the standard acceleration of gravity, experienced as weight], de-escalating from aerodynamic red zones and nominally reducing

Operational and Training Flight Envelopes



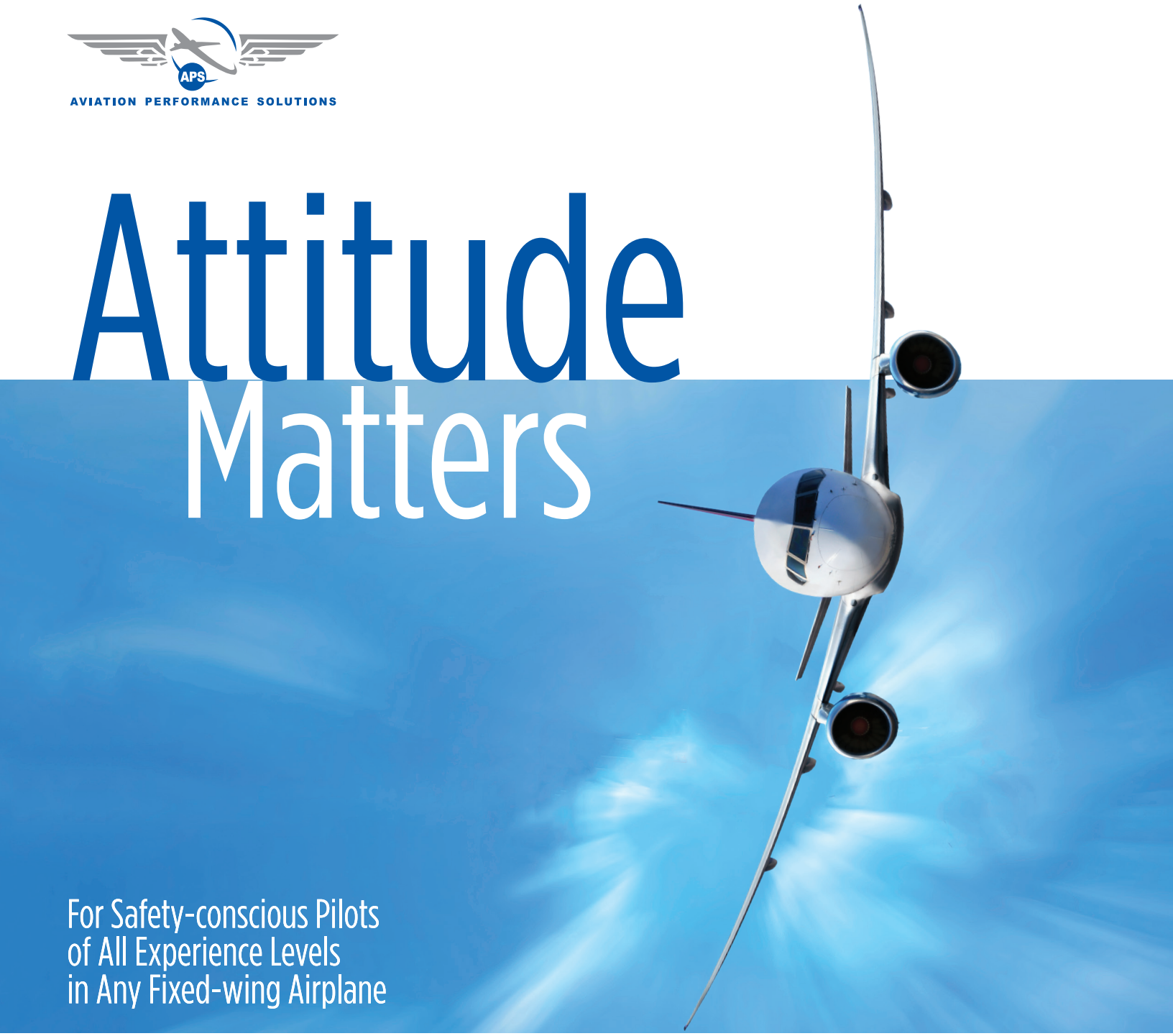
AOB = angle of bank; ICAO = International Civil Aviation Organization

Source: ICAO *Manual on Aeroplane Upset and Recovery Training*

Figure 1

AVIATION PERFORMANCE SOLUTIONS

Attitude Matters



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stress on the pilot. This precursor action also results in an improved 'roll' response. The magnitude of the 'push' on the elevator control, however, is generally notably smaller compared to the aileron input applied during the 'roll.'"

Common errors — such as reversing the order of the 'push-then-roll' sequence — can occur under the pressure of a roll upset, they noted.

"Many … correctable pilot errors do not manifest until beyond 90 degrees of bank and will exacerbate as bank angle approaches 180 degrees," according to the paper. "Consequently, progressively escalating into the red zone will allow the pilot to practice the 'push-then-roll' technique at lower bank angles and reduced stress levels. Training can then proceed beyond 90 degrees, where potentially debilitating effects such as startle can be worked through while simultaneously executing 'push-then-roll' actions. Thus, on-airplane exploration of bank angles from 90 degrees up to 180 degrees (the worst-case scenario) will be critical to the success of recovering from real-world upsets."

Angle-of-Attack Threats

Another class of upsets can arise from mismanagement of angle-of-attack, when the coefficient of lift decays in connection with airspeed. Unless corrected, a stall can result. Similarly to training for recovery from the flight envelope red zone, UPRT gives pilots the experience of dealing with high angle-of-attack situations. Again, the inappropriate angle-of-attack is progressively increased so that the trainee gradually gets used to the phenomenon and its proper response, while developing confidence.

"Undesirable changes in flight characteristics and their ramifications [for] controlled flight only reveal themselves during high angle-of-attack flight," the authors say. "The aggravating effects of instinctive reactions by the pilot are revealed only as control effectiveness decays at high angle-of-attack and the airplane begins to exhibit post-stall behavior. Red-zone angles-of-attack must therefore be experienced not only to mitigate the potential merging of unfavorable aerodynamic and psycho-physiological factors, but also to maximize the beneficial effects of adrenalized learning."

As during excursions from the normal flight envelope, the internalized mitigation bridge enables rapid recovery. This training method also reinforces that recovery techniques should begin at the first sign of a dangerous angle-of-attack or yaw, not waiting for a specific upset parameter (Figure 3, p. 21).

Inclined Planes

"Regardless of the airplane being used, the safe and legal delivery of UPRT requires due consideration of the training airplane's approved operating limitations, design limits, and available margins of safety," the paper says. "The success of UPRT will also depend on buy-in from both aircraft manufacturers and insurance underwriters — without their support, efforts to deliver practical UPRT will be stymied."

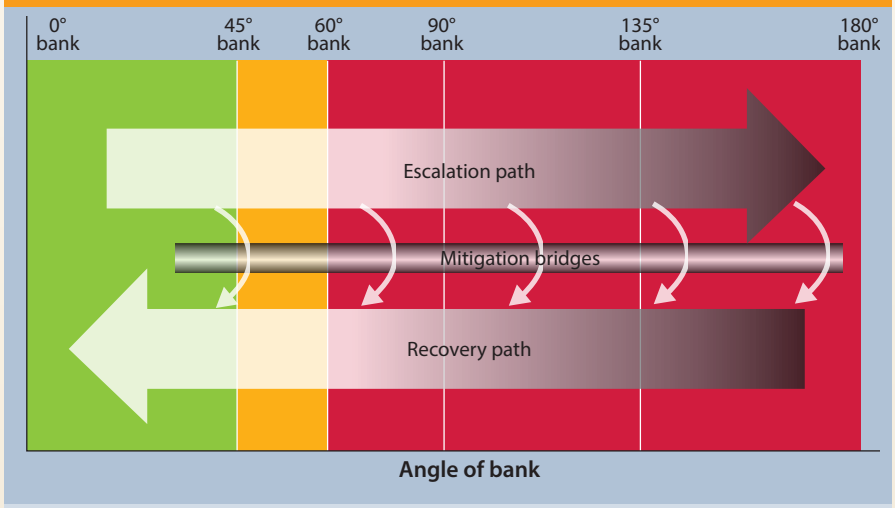
In the United States, for example, approved maneuvers for different categories of airplanes are described in U.S. Federal Aviation Regulations (FARs) Part 23.3:

- The *normal* category is intended for nonacrobatic operations. The authors noted, "Thus, in the normal category, operating limitations prohibit intentional maneuvers that exceed 60 degrees of bank. Intentional spins are prohibited as well."
- The *utility* category may be used in limited acrobatic operations. The authors note, "Operating limitations prohibit intentional maneuvers that exceed 90 degrees of bank. Intentional maneuvers with bank angles in excess of 60 degrees, however, will require approved parachutes to be worn by the trainee and the instructor. Whether or not intentional spins are approved in the utility category depends on the particular aircraft."
- The *acrobatic* category carries no restrictions other than those shown to be necessary in flight tests. The authors say, "Intentional maneuvers with bank angles in excess of 60 degrees, however, will still require approved parachutes to be worn by the trainee and the instructor. Intentional spins are approved in the acrobatic category (notwithstanding airworthiness directives or supplemental type certificates that may affect the spins-approved status). An accidental spin in the acrobatic category could have up to a six-turn margin of safety wherein recovery can be assured, provided proper spin-recovery actions are implemented and sufficient altitude remains in which to recover."

Considerations besides airplane category apply, however. Structural design limits also depend on flaps configuration (deployed or not) and how g-load is applied (symmetrically or asymmetrically).

"In the acrobatic category, design limits with flaps up and symmetrical g-load are positive 6.0 g and negative 3.0 g," the paper says. "The design limit when simultaneously rolling and pulling, however, drops to positive 4.0 g. Thus the structural margin of safety

Concept of Mitigation Bridges in Recovery: Excessive Bank Angle

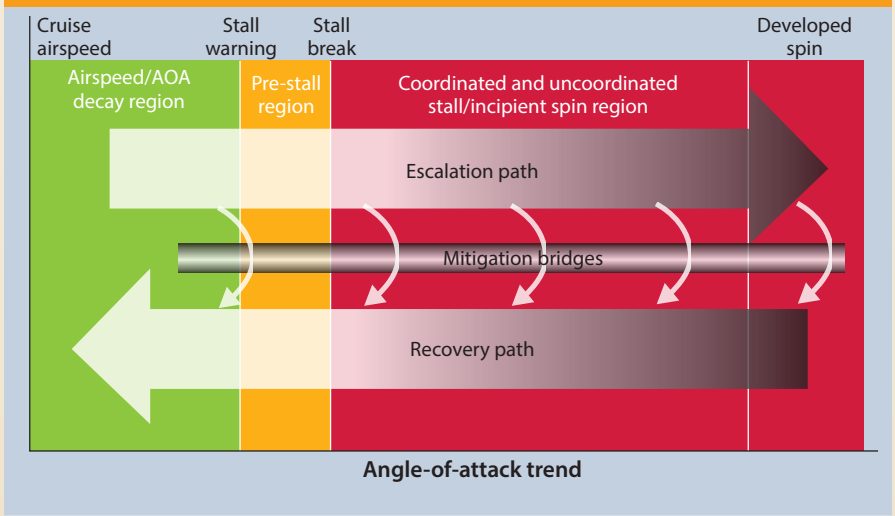


ICAO = International Civil Aviation Organization

Source: ICAO *Manual on Aeroplane Upset and Recovery Training*

Figure 2

Stall/Spin Escalation and Recovery Paths



AOA = angle-of-attack; ICAO = International Civil Aviation Organization

Source: ICAO *Manual on Aeroplane Upset and Recovery Training*

Figure 3

in the acrobatic category during an inadvertent rolling pullout would be positive 4.0 g, provided the flaps were retracted."

The possibility of airplane structural fatigue must also be monitored. "There is an exponential relationship between g-load and the fatigue life of wing structures, engine mounts, seat frames, windows and other major components. … [R]elatively small increases in g-load can result in dramatically reduced life cycles," the authors say.

"While perhaps not the deformation or catastrophic failure concern associated with design limits, structural fatigue definitely impacts the cost of, and comfort with, the delivery of UPRT. Higher g-loads can lead to increased aircraft maintenance and downtime — translating into increased [training] delivery costs — as well as increased risk to pilots flying the subject airplanes."

Specialized Equipment

For airplanes regularly engaged in UPRT, extra equipment is either required by regulations or installed for optimal pilot safety. The authors say that among these items typically are:

- Parachutes — "With the exception of spin training, [FARs Part] 91.307 stipulates that no pilot of a civil airplane carrying any person (other than a required crewmember) may execute an intentional maneuver that exceeds 60 degrees of bank or 30 degrees of pitch relative to the horizon, unless each occupant is wearing an approved parachute that has been repacked at specified intervals."

- G-meters — "Airplanes approved for use in the acrobatic category are typically equipped with g-meters. This instrument not only allows the monitoring of the stresses imposed on training airplanes, but it also provides important context during UPRT to calibrate trainees to acceptable load factors [in relation to] design structural limitations."

- Emergency egress — "Airplanes approved for use in the acrobatic category are typically equipped with doors, canopies and windows that are capable of being jettisoned for in-flight emergency egress."

- Seat belts — "Airplanes approved for use in the acrobatic category are typically equipped with dual lap-belt systems. This redundancy provides a greater margin of safety should a lap belt attach point fail or a pilot inadvertently unlatch a lap belt during UPRT."

To Instruct and Serve

Another critical element in on-airplane UPRT, besides the adrenalized learning and the aircraft and equipment considerations, is the flight instructor's qualifications.

"A qualified instructor is arguably the single greatest asset to UPRT, not just for the delivery of the requisite academic and practical training, but also for the mitigation of risks associated with the training itself," the paper says. "Conversely, an unqualified instructor will quickly become the greatest liability to the success of the UPRT initiative. The qualifications of on-airplane instructors, in particular, require special consideration if the benefits envisioned from UPRT are to be realized."

The certified flight instructor granted privileges by the regulator for typical flight instruction, who has not completed UPRT-instructor training, lacks the necessary background for UPRT, Brooks, Ransbury and Stowell say. Those with only the flight instructor rating generally have limited experience in beyond-normal attitudes and flight envelopes, and little or no competence in acrobatics or recovery from substantial spins; most qualified as instructors flying light general aviation aircraft in the normal category, they say.

"As the UPRT initiative expands and evolves from an unregulated to a regulated state … new concepts will be injected into the aviation lexicon and new knowledge and skills will become a core competency for all professional pilots," their paper says. "The specific competencies demanded of UPRT instructors do not exist in current instructor training and certification requirements. Even current stall and spin awareness training mandates for flight instructor applicants have proven inadequate, resulting in demonstrable — and almost universal — deficiencies in both instructor understanding of high angle-of-attack dynamics and instructor competency relative to providing adequate stall and spin instruction.[9]

"The on-airplane UPRT environment necessitates high levels of instructor competency in, and comfort with, the flight regimes well beyond normal operations, the performance and operating limitations of different training aircraft and the ability to respond appropriately to inadvertent upsets encountered in the training environment. A failure to adequately qualify UPRT instructors from the outset could have dire consequences on safety and thus on broad acceptance of the UPRT philosophy."

Notes

1. Boeing Commercial Airplanes. *Statistical Summary of Commercial Jet Airplane Accidents, Worldwide Operations, 1959–2012.* <www.boeing.com/news/techissues/pdf/statsum.pdf>.

2. A draft of the proposed *Manual* was submitted to ICAO in December 2012 by the International Committee for Aviation Training in Extended Envelopes. The committee completed its four-year, multiphase LOC-I mitigation initiative in 2013.

3. The UPRTA website describes the association as "an international aviation organization devoted to flight training quality assurance and instructor pilot standardization." <uprta.org/uprta-mission-to-enhance-safety-of-air-travel>.

4. Available at <uprta.org/uprta-paper-addresses-icao-manual-on-aeroplane-upset-prevention-and-recovery-training>. For consistency with the *Manual*, the paper used the spelling *aeroplane*. In this article, *airplane* has been substituted.

5. The term *UPRT* was adopted by both ICAO and the U.S. Federal Aviation Administration to resolve earlier variations in terminology, including *emergency maneuver training*, *advanced maneuver training* and *upset recovery training*.

6. Randy Brooks is a master instructor, member of the Society of Aviation and Flight Educators (SAFE), UPRT instructor and vice president of training for Aviation Performance Solutions with a background in many facets of business aviation. His air show acrobatic experience includes formation team demonstrations, jet aircraft and sailplanes. He has delivered more than 3,000 hours of flight instruction and is president of UPRTA.

   Paul "BJ" Ransbury is the president of Aviation Performance Solutions, a multinational flight school that trains more than 1,000 professional jet pilots annually in integrated UPRT. He is a four-time master instructor, SAFE member, former airline pilot and military fighter pilot.

   Rich Stowell is an eight-time master instructor, SAFE member, the 2014 National FAA Safety Team Rep of the Year and the 2006 National Flight Instructor of the Year. He has been a full-time instructor specializing in spin and emergency maneuver training since 1987, and is the author of three aviation textbooks.

7. Cahill, L.; McGaugh, J. "Mechanisms of Emotional Arousal and Lasting Declarative Memory." *Trends in Neurosciences* Volume 21(7), 1988.

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