Rethinking Upset Training
Using simulators to develop upset-recovery procedures could lead to negative training

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Airline pilots who have completed upset recovery training may discover that a real aircraft actually responds quite differently than their companies' motion-base simulators, possibly leading to inadvertent loss of control during an actual inflight emergency.

Further, pilots can be trained to use rudder inappropriately and actually cause structural damage or loss of a tail fin by aggressively cycling the rudder during an upset event.

These and related issues are being explored by the Society of Automotive Engineers' S7 committee, which deals with transport-category aircraft flight deck and handling qualities standards. Work is ongoing, but the committee expects to issue its findings in a new SAE Aerospace Information Report this year.

Motion-base simulators' aerodynamic models and "feel" cues, such as g-loads (Nz), often are not representative of actual aircraft flying outside their normal operating envelopes.

A status report on the committee's progress was outlined in a technical paper written for the Society of Experimental Test Pilots' (SETP) 47th symposium. Steve Stowe, a captain for Delta Air Lines, and Tom Melody, director of flight operations for Boeing Commercial Airplanes-Long Beach (Calif.), jointly presented the paper to approximately 900 attendees. Stowe serves as chairman of the SAE S7 committee, and Melody is a current member. Both are former U.S. Air Force test pilots and had tours as USAF Test Pilot School instructors. Melody was a test pilot on the first flights of then-McDonnell Douglas MD-88 and MD-11, and Boeing 717 transports. Stowe has more than 13,000 hr. in more than 140 aircraft types, and is rated on the Boeing 727, 737, 757, 767 and MD-11.

Following the loss, in November 2001, of American Airlines' Flight 587 due to tail fin failure after the Airbus A300 encountered a mild wake vortex from a Boeing 747, the SAE S7 committee started exploring several related issues:

- When and how rudder should be used during upset recoveries in large air transports.
- What role ground-based simulators play in developing upset-recovery procedures.
- Rudder control system harmony—how much rudder pedal force translates to actual rudder deflection.
- Inertial effects cause delays, especially sideslip can lead to loss of control. "That works in smaller airplanes, like a [Beech] T-34— but probably isn't the best initial maneuver in a large airplane," Stowe said.

In 1998, aircraft manufacturers Boeing, Airbus and then-McDonnell Douglas issued recommendations to use full aileron inputs for primary roll control after a lateral upset, adding rudder only if the response to ailerons wasn't quick enough. A joint-manufacturer flight test department bulletin warned: "... the amount of rudder needed will depend on the airplane type and systems. However, at high AOA [angle-of-attack], pilots must be extremely careful when using rudder for assisting lateral control as excessive sideslip can lead to loss of control."

If, however, the upset pilots' warnings may not have been fully incorporated into airline upset-training curriculums. Stowe explained, "You don't want to use rudder as your initial or primary roll control, because it's not as easy to control sideslip in big airplanes as it is in small ones. Inertial effects cause delays, and rudder [response] isn't precise. You can build up large sideslip angles, even after you take the rudder deflection out. That can cause what appears to be an abrupt onset of roll."

Aggressive rudder inputs to arrest that rolling motion, coupled with delayed aircraft response, can lead to large rudder inputs in the opposite direction, triggering subsequent large-amplitude oscillations in roll and yaw, the committee determined. The resulting excessive sideslip can lead to loss of control, and "overstressing" might "overstress the vertical tail, even at airspeeds less than the handbook maneuvering speed," according to the SETP paper. An independent examination by Aviation Week & Space Technology came to similar conclusions (AW&ST Nov. 25, 2002, p. 44).

Further, after an upset or uncommanded excursion caused by turbulence, a wake-vortex encounter, flight control system hardover or other trigger mechanism, "you can find yourself at a high angle-of-attack. Then you'd better be real careful with the use of rudder. To depart [from controlled flight], you just have to stall it and yaw it," Stowe said.

The SAE S7 committee also found that training simulators are inappropriate for developing upset recovery techniques, because their aerodynamic models aren't always accurate outside normal operating envelopes. Airline training departments need to be aware that simulator fidelity simply isn't good enough to accurately depict aircraft responses after an upset, Stowe and Melody noted.

For example, one airline had developed
oped an upset-training profile that injected a rapid roll rate into the simulator, but artificially inhibited the roll control response—spoiler effectiveness—until the “aircraft” rolled past 135 deg. of bank. “So, they were giving pilots the illusion that the only thing that would roll the aircraft was rudder—which wasn’t the same as the airplane’s [actual control mode],” Stowe said. “It’s OK to train in a simulator, but don’t use the simulator to develop procedures. And don’t validate a profile and procedures in the simulator without getting the [aircraft] manufacturer involved. We don’t want [training instructors] saying, ‘My idea works in the simulator, so we’re going to use it in the [actual] airplane.’

“SAE S7 believes that, in general, an [effective] upset recovery would involve first disconnecting the automation (autopilot and autothrottles), then controlling AOA as the first order of business. Then get your velocity vector pointed where you want it to go, followed by analyzing the situation,” Stowe added.

The committee also is questioning “rudder control harmony” in some aircraft. Most have force-deflection profiles that closely relate rudder pedal force and rudder surface travel. In other words, after a pilot exerts enough pedal pressure to exceed the “breakout force” and make the rudder start moving, the resulting control surface deflection is proportional to rudder pedal force. However, the committee noted that, at high speeds, the A300-600’s rudder limiter restricts travel to ±9.3 deg. as a protection feature—but pedal force required to get that much travel is only 10 lb. above breakout force. The aircraft has a rudder breakout force of about 22 lb., but only another 10 lb. of force is needed to drive the control surface to its full available travel (9.3 deg.).

“That doesn’t seem to be an ideal system—to have two-thirds of the force profile devoted to overcoming friction and breakout [forces], then only one-third left to get full [allowable] rudder deflection,” Stowe said. Veridian and NASA Langley experts agreed.

Depending on manufacturers’ feedback, the SAE S7 group may advocate changing SAE Aerospace Recommended Practice 4104’s section on rudder harmony to promote a better relationship between breakout- and maximum-forces. That particular ARP is devoted to transport aircraft handling qualities and stability and control.

The committee also expects to recommend that manufacturers incorporate more flight-envelope protection schemes into flight control system designs.