

# Simple tools to PREVENT LOC

Practical, low-cost technologies are within reach to reduce the risk of loss of control.

BY DON BATEMAN

Loss of control (LOC) and lack of aircraft control (LAC) accidents continue to mar commercial aviation's great safety record, but there are cost-effective technologies that could help reduce the risk of these accidents years before more elegant and sophisticated systems can be created and fitted to new aircraft designs.<sup>1</sup>

LOC and LAC currently are the leading causes of fatalities in commercial aviation. There were 34 accidents in the last 10 years that cost more than 3,100 lives and \$4 billion in financial losses. Spatial disorientation and suspected reversion or confusion between Western and Eastern (Soviet-era) attitude indicator formats accounted for nearly half of the losses (Figure 1). Undetected airspeed decreases leading to stalls were involved in about 20 percent of the losses.

In the "Others" category are wake turbulence upsets, a growing risk as RNP (reduced navigation performance) procedures increasingly confine aircraft tracks during departure and initial approach. Other causes of LOC/LAC are pilot training practices that foster overcontrol of the rudder, autopilot mode confusion and failure to decrease angle-of-attack (AOA) to regain control.

## Display Disorientation

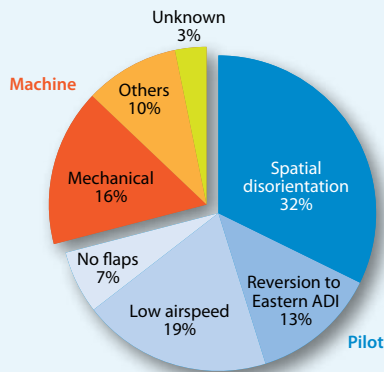
The attitude director indicator (ADI) is a key instrument for manual flight control and for monitoring automatic flight control. However, when a pilot attempts to recover from an unusual attitude, an unfamiliar ADI display can cause or contribute to confusion, uncertainty and/or delay.

The unfamiliarity typically is introduced by Eastern versus Western display formats (Figure 2). Overcoming a lifetime of flying experience with either type can prove to be very difficult for a pilot transitioning to the other type of display.

The major differences in these formats are that the Western horizon line tilts in alignment with the outside horizon and the airplane symbol remains fixed horizontally, while the Eastern horizon line remains horizontal and the airplane symbol tilts to show the airplane's bank angle. The Western format is an "inside out" display, while the Eastern format is an "outside in" display. The latter is the picture that the pilot of a following aircraft would see of the preceding aircraft. Military pilots often claim it is a better display when maneuvering in fast combat.

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## LOC/LAC Accident Factors



LOC = loss of control; LAC = lack of aircraft control; ADI = attitude director indicator

Source: Don Bateman

**Figure 1**

The Eastern ADI was designed in the early 1920s. It is less complex mechanically and simpler to build. Many pilots trained on this display format have had difficulty adapting in abnormal or unusual attitude situations to the ADIs in Western-built aircraft acquired by Eastern operators in the 1990s.

With the concepts and knowledge available today, a better, “universal” ADI could be developed to help reduce the learning time required during transition and to improve the probability of recovery when a pilot suddenly encounters an unusual attitude.

In 1966, Honeywell developed the *positive attitude control system*, a modified helicopter ADI intended to aid pilots, especially inexperienced pilots, in quickly learning to control helicopters in “brownouts” caused by blown-up dust, at night and in other reduced-visibility conditions. The system enabled the pilot to use the cyclic control to position the aircraft symbol on the ADI to the desired attitude. The symbol would gradually wash out as the roll and pitch attitudes were adjusted, and then return to its normal centered position on the ADI.

The mechanization gave an excellent stability control margin even in turbulence.

It was amazing how a pilot with little or no experience in fixed-wing aircraft or in helicopters could quickly adapt and easily control a helicopter in flight.

The evolution of “glass” cockpits with electronic flight information systems (EFIS) and electronic ADIs makes this abandoned and essentially forgotten concept now very practical.

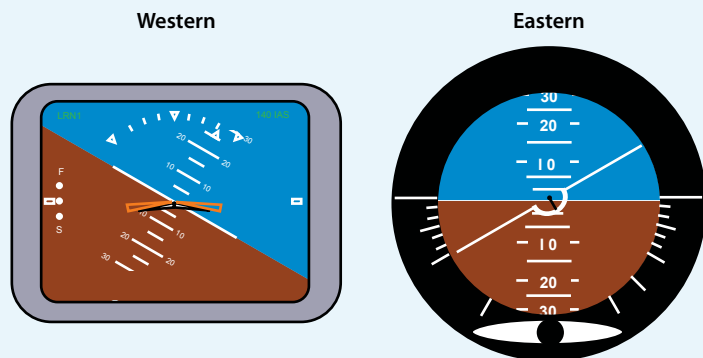
### This Way Up

The risk of LOC is at least 10 times higher for aircraft with conventional pulley-and-cable controls than for fly-by-wire (FBW) aircraft with automatic protective envelopes. The greatest challenge is recovery from an inadvertent excessive bank angle when the pilot either believes that the autopilot is engaged or has tried to engage the autopilot after being startled by the unusual attitude.

Bank angles exceeding 35 degrees in conventional pulley-and-cable aircraft are common in real-world operations. Enhanced ground-proximity warning system (EGPWS) data recorded during 9 million flight departures shows a rate of about 1.8 bank angle exceedances per 1,000 departures.

Safety specialists are considering the use of roll and pitch recovery “arrows” on ADI/EFIS displays to help pilots recover from unusual attitudes (Figure 3, p. 30). In a simulation study,

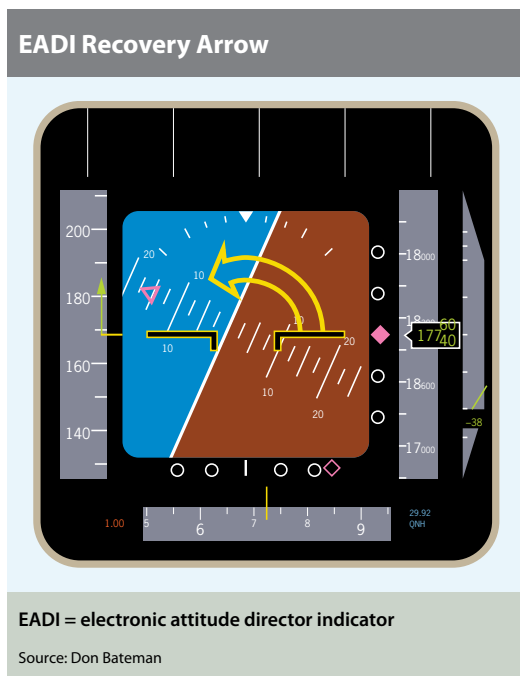
## ADI Display Formats



ADI = attitude director indicator

Source: Don Bateman

**Figure 2**



**Figure 3**

Gary Gershzo of Boeing showed that a recovery arrow helped reduce errors by 90 percent.<sup>2</sup> Participating pilots could quickly and correctly determine how to correct the bank angle. For many existing ADI/EFIS displays, this could be a modification with minimum investment.

The EGPWS computers currently installed in more than 42,000 aircraft provide an optional “BANK ANGLE”

warning when bank exceeds 35 degrees. Honeywell is considering the addition of an aural advisory such as: “Roll left to level.” The EGPWS computer simultaneously could provide a signal to the ADI that would activate the recovery arrow. These would be relatively simple software changes to most EGPWS computers and ADI/EFIS displays.

### Synthetic Displays

If the pilot can see the horizon clearly outside the aircraft, the probability of LOC is very low. When the pilot cannot see the horizon, a synthetic vision system (SVS) can display an outside view overlaid with primary flight instrument indications similar to those found on a head-up display (HUD).

Both SVS and HUD are very valuable tools for LOC avoidance. Nonessential information can be removed automatically from the display to help the pilot concentrate on recovery from an unusual attitude.

Another possible improvement for conventional-control aircraft is tactile warning of excessive bank angle, such as a “stick nudge” based on aileron or control wheel

position. This would be similar to a pre-stall stick shaker.

Honeywell has experimented with a simple device installed in a Beech King Air. The stick nudge was designed to be fail-safe to prevent the possibility of jamming the control cables. The advantages of the device are its simplicity and no change to the existing rigging or cable controls.

### Aural Alerts

A number of accidents have involved pilots who did not notice a progressive loss of airspeed until the stick shaker activated with insufficient altitude to recover. These comprised about 20 percent of all LOC/LAC accidents.

The U.S. National Transportation Safety Board has repeatedly recommended installation of an aural and visual airspeed-alerting system. One FBW aircraft manufacturer has added an aural “AIRSPEED” alert to help pilots identify the need to reduce AOA when it reaches a protective envelope maximum value.

The ADI/EFIS displays in some conventional-control aircraft have a box around the airspeed readout that flashes at the minimum operating speed. Unfortunately, if the pilot is not scanning the airspeed readout, he or she might not notice the silent flashing box. An optional aural alert, “AIRSPEED LOW,” has been developed to supplement the flashing airspeed box. This is a software function hosted in the EGPWS computer and requires no change to hardware or aircraft wiring.

Some accidents and incidents have involved aircraft that lost airspeed or AOA indications, or that had unreliable indications. Many were caused by sensor orifices blocked or restricted by tape applied during painting or by other contaminants.

A useful option offered by Airbus for both long-range and single-aisle aircraft is a backup airspeed scale and altitude scale that replace the normal scales when all three air data references are disengaged due to unreliable speed/altitude indications. The backup speed scale information is based on AOA and depends on the slat/flap configuration.

The backup altitude scale displays the global positioning system (GPS) altitude.

### No-Flaps Alert

Accidents have resulted from attempts by flight crews to take off with the flaps improperly set. Most of the accidents involved unrecognizable takeoff warnings generated by the configuration warning systems or systems that were inoperative. Contributing factors included warning horns that can mean other problems with configuration, such as stabilizer trim, mismatched flaps or asymmetric thrust.

There also have been many incidents in which crews heard the configuration warning horn as they advanced the thrust levers. The wise pilots immediately rejected the takeoff and pulled off the runway to properly set the flaps. Some not-so-wise pilots attempted to set the flaps during the takeoff run, believing that the runway was long enough to do so.

One simple way to reduce the risk is to provide an aural “CHECK FLAPS” message when an aircraft enters a runway for takeoff without takeoff flaps set. This is possible, without hardware or wiring changes, with current EGPWS equipment that uses flap position to enable reactive wind shear functions. Acceptable takeoff flap setting data are all that is required. EGPWS already has sufficient runway data to create a “virtual box” around the runway. The hosted takeoff function would be completely independent of the configuration warning system and could also provide a visual text message, “FLAPS,” on an existing display.

### Wake Turbulence ‘Tails’

Many LOC incidents and a few accidents have been caused by inadvertent flight into wake turbulence. The risk of these events could be decreased by adding “tails” to displayed Automatic Dependent Surveillance–Broadcast (ADS-B) targets to represent possible vortex locations and strengths (Figure 4).

Engineers tend to overcomplicate the computation of vortex locations and intensities. But a simple algorithm based on Isaac Newton’s

momentum flow, which gives an airplane its lift, would provide a good first-order approximation of vortex locations. Wind information, the other aircraft’s position and other aircraft data would improve the calculation of where the wake turbulence probably exists.

Displaying areas to avoid or stay above would be a powerful tool for pilot awareness of wake turbulence and potential LOC.

### Improve Training

Even the best technology can be of limited effectiveness without good professional training. Exposing the pilot to unusual attitudes and recoveries in a simulator, especially with the particular ADI/EFIS that the pilot uses in everyday operations, is invaluable.

Airmanship needs to be practiced and enforced with proven standard operating procedures and knowledge gained from real-world experience and from research and development. Ingenuity and innovation can help drive down simulator costs so that every transport pilot can learn and handle somatogravic illusions.<sup>3</sup>

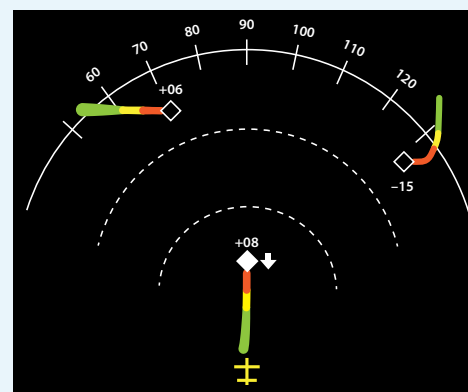
The advanced maneuver and upset recovery training being practiced by several airlines should greatly reduce LOC risk.

### Soft Protection

Another possible LOC/LAC solution is to utilize existing autopilot servos and servo amplifiers to automatically avoid unusual roll and pitch attitudes. The autopilot servos installed in almost every airplane today are torque-limited, which allows the pilot to overpower the servo if necessary. This would also help give tactile feedback in the form of a “soft protection” for the aircraft.

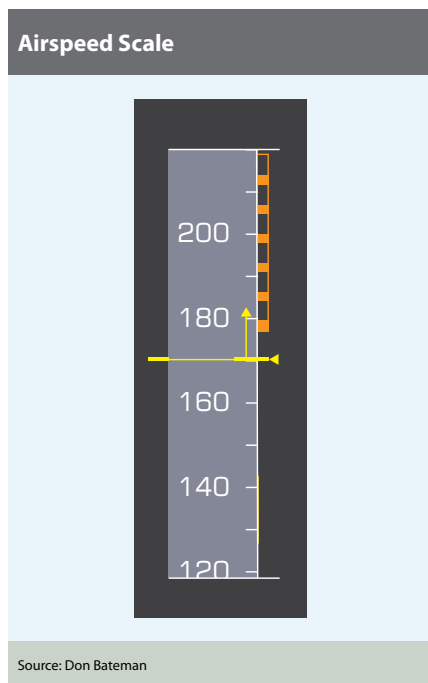
**Even the best technology can be of limited effectiveness without good professional training.**

Wake Turbulence Display



Source: Don Bateman

Figure 4



Source: Don Bateman

**Figure 5**

Unfortunately, the complexities of certification and application of using existing autopilot components could be very difficult and probably too expensive to implement.

As discussed earlier, FBW aircraft with full or resistive tactile protective envelopes have proven in service to be significantly resistant to the excessive bank angles that can lead to LOC. However, these aircraft are not immune to flight into terrain or to inducing somatogravic illusion that could lead to an inadvertent pitch down during a go-around close to the ground. There have been at least two accidents in which the pilots did not respond to EGPWS warnings and flew into water or ground while executing a go-around.

One of the weaknesses of some FBW aircraft designs is the lack of tactile feedback from sidesticks and the possibility of both pilots adding or subtracting their stick input. Sidesticks that provide tactile feedback are now available and should be used.

The lack of tactile feedback from thrust levers while changing power is another weakness of FBW designs.

Honeywell successfully demonstrated automatic recoveries in 2005 using an “assisted recovery” algorithm for autopilots in both conventional and FBW aircraft. Recoveries were made from flight paths toward mountainous terrain and obstacles.

A simple dive-recovery and wings-level algorithm would suffice to prevent most FBW aircraft accidents short of the runway. The level of integrity must be high to prevent inadvertent activations.

To ensure the integrity of runway terrain and obstacle data, EGPWS flight history currently is accumulated automatically in nonvolatile memory for all alerts and warnings. Flight history also is retained for every approach and take-off in GPS WGS-84 latitude-longitude, altitude and track coordinates. The data are then audited to validate accuracy and nuisance-free operation.

### Reverse the Tape

I believe that the EFIS airspeed tape, or scale, used on most transport aircraft should be reversed.

The scale typically has a red-stripped box bordering the speeds at which flap and aircraft overspeed occur (Figure 5). As airspeed increases and the trend arrow points into the overspeed-warning box — both upward movements on the scale — the pilot’s natural reaction is to push forward on the control column, inadvertently increasing airspeed further.

There have been accidents and incidents in which a flap overspeed alert coupled with spatial disorientation likely contributed to a critical distraction at a critical time, leading to LOC.

In the 1980s, there was considerable debate over airspeed scale orientation. The industry gravitated toward the rising scale, and thousands of aircraft now have them. Thus, although reversing the scale would involve only a simple program pin and wire relocation, the change might be seen as introducing difficult training and adaptation problems for pilots. However, some operators have experienced no such problems for pilots flying either airspeed tape orientation in the same business aircraft type.

With losses from LOC/LAC accidents averaging about 300 lives and \$400 million per year, the industry must focus on practical technology solutions for conventional and FBW aircraft. ➔

*Don Bateman, chief engineer for flight safety technologies at Honeywell Aerospace, led engineering teams in the development of the ground-proximity warning system (GPWS) and the enhanced GPWS. This article was adapted from the author’s presentation to the FSF European Aviation Safety Seminar in March 2011. The opinions expressed do not necessarily reflect those of Honeywell or the Flight Safety Foundation.*

### Notes

1. A *loss of control accident* is one in which an aircraft is unintentionally flown into a position from which the flight crew is unable to recover due to aircrew, aircraft and/or environmental factors. A *lack of aircraft control accident* is one in which a controllable aircraft is unintentionally flown into a position from which the crew fails to recover due to aircrew, aircraft and/or environmental factors.
2. Gershzojn, Gary. “Unusual Attitude Recovery With the Roll Arrow.” Presented at the FSF 16th Annual European Aviation Safety Seminar, March 2004.
3. *Somatogravic illusion* is a false sensation that the airplane is climbing when it actually is accelerating. A pilot may react by decreasing AOA.