Loss of Control Due to Flight Crew Loss of Airplane State Awareness: Analysis and Safety Enhancements

Presented at RASG-AFI LOC-I symposium, Nairobi 22 June 2015
by
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Accident Categories
Change over time

Fatal Accidents – Worldwide Commercial Jet Fleet

- CFIT
- LOC In-Flight
- Mid-Air Collision
- Fire/Smoke (non impact)
- Runway Excursion (T/O & Ldg) +ARC+ USOS
- Runway Incursion

Fatalities
0 500 1000 1500 2000 2500 3000

1993 - 2002
1998 - 2007
2003 - 2012

Yearly Fatalities:
- 1993-2002: 2186

CFIT: 1207, 972, 972
LOC In-Flight: 1931, 1931, 1931
Mid-Air Collision: 420, 225, 156
Fire/Smoke (non impact): 455, 114, 4
Runway Excursion (T/O & Ldg) +ARC+ USOS: 301, 826, 985
Runway Incursion: 208, 203, 0
Airplane State Awareness Contribution

- 1648 (50) External Fatalities [139]
- 971 (1) Onboard Fatalities [4269]
- 765 (28) Attitude awareness [674]
- 153 (12) Energy state awareness [596]*

* does not include Colgan 3407 or other turboprop accidents
Example of Overbank from ASA Event Set
Kenya Airways 507 - Douala, Cameroon
Boeing 737-800 - May 5, 2007 - 114 fatalities
Example of Overbank from ASA Event Set
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- During initial climb at 1000 ft AGL with autopilot disconnected

- Bank angle increases from 20° to 35° over roughly thirty seconds at normal g

- No initial input from the PF (from CVR, crew likely believes autopilot engaged): loss of attitude awareness

- At 35° bank, PF control wheel: right, left, right (mostly right) over 20 sec

- Bank angle increases past 90° and vertical speed goes from positive to negative
Event Type: Loss of Attitude Awareness
Injuries/Fatalities: 114 fatalities: 108 passengers / 6 crew; no survivors; airplane destroyed
Flight: Kenya Airways 507
Local Time: 12:07 am

Narrative
- Capt is PF; 8682 ttl hrs; type: 824 (Capt on 737-700/800);
- FO has 831 ttl hrs; type: 170; FO hadn’t had CRM training yet
- Flight crew training did not provide: UAR, SD
- Local weather: thunderstorms and moderate rain; 800 m visibility, scattered 300 ft, broken 1000 ft
  - Initially canceled start-up due to heavy rain; prior to take-off they are focused on identifying a departure corridor away from weather
  - On take-off the airplane has a tendency to bank right (not trimmed) and the Capt uses small left wheel inputs to maintain wings level
  - At about 1000 ft, a period of 55 seconds commences where there are no control inputs; airplane begins slowly rolling right
  - Attention at this time is on navigating through the weather
  - 13 seconds after the last control input, Capt: “OK, command”; but the autopilot is not engaged (and there is no response from the FO); they are at 1600 ft and bank right of 11º
    - They are attempting to use the heading bug to maneuver around the weather for 40 more seconds, but the heading bug has no effect since autopilot is not engaged.
  - As bank angle nears 35º, the Capt exclaims and then EGPWS: “bank angle, bank angle”
  - Capt makes wheel inputs to right, then left, then right with inputs to right dominating; airplane rolls to 45º right
  - They engage the autopilot but due to force on wheel, transitions into CWS-R
    - Capt makes inputs to right and left, and pulls back on wheel; bank angle eventually reaches 115º to the right, but is recovered to 70º right
    - The FO states, “right captain, left, left, left, correction left.”
  - Capt and FO are both on controls; Capt rolling right; FO rolling left

Event: Kenya Airways 737-800 near Douala, Cameroon on 4 May 2007

Flight: Kenya Airways 507
Registration: 5Y-KYA
Phase of Flight: Climb to Cruise

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Example of Speed Decay/Stall from ASA Event Set
West Caribbean Airways 701 – Venezuela
Boeing MD-82 - August 15, 2005 - 160 fatalities

- Engine anti-ice turned off to climb to FL330
- Engine anti-ice re-engaged; EPR reduced
- A/P in altitude hold
- Airspeed and Mach decay over next 10 minutes
- Autopilot disconnected
- Stall warning – pilot responds with full aft column and NU trim
Narrative

1. Significant safety oversight issues at operator for previous 6 months
   - CAPT experienced but low time in type; FO had low time but more in type
   - Takeoff at or near max allowable weight (performance limited)
2. Flight plan called for cruise at FL350; airplane not capable of achieving altitude with anti-ice
3. Significant weather along the planned route; not noted on the flight plan
4. Night, IMC. Middle of the night for crew’s Circadian rhythm.
   - Initial cruise at FL310 encountered weather cells, routed around by ATC
   - Crew requested climb to FL330 but could not reach altitude in level change mode
5. Crew turned off anti-ice; switched to VS; aircraft climbed at max power, losing airspeed
6. At FL330, crew restored anti-ice, re-engaged A/P in ALT HOLD, commenced other activities
7. Aircraft could not maintain altitude at selected airspeed; Mach began to decrease
   - As Mach decreased to 0.65, airplane also began to lose altitude
   - Crew asked ATC for lower altitude and began to descend as Mach decreased below 0.60M
   - Just below FL320 stick shaker activated
8. CAPT disengaged autopilot and pulled the column aft, then began to trim nose up
9. Autothrottles remained engaged, throttles to idle (reasons unclear, possibly from surge)
10. Aircraft entered full stall. FO recognized stall but did not intervene. CAPT did not respond to FO
11. Crew mistook idle thrust as indication of engine flameout, contact ATC to declare emergency and request lower altitude
12. CAPT continued to hold column aft as crew continued to call for lower altitudes and diagnose perceived engine trouble
   - Crew apparently believed the reduced airspeed was the result of dual engine flameout. The CAPT never attempted to reduce angle of attack.
   - Descent reached 12,000 fpm just before the airplane impacted the ground.
# ASA Significant Themes

## Summary of Significant Themes Across All Events

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ASA Proposed Safety Enhancements
Recommended Safety Enhancements
Air Carrier Actions

• Low Airspeed Alerting
  • Incorporate existing service bulletins to install low airspeed aural alerting in the U.S. fleet

• SOP Effectiveness and Adherence
  • Review and update SOPs to align with latest CAST, manufacturer, and ATO recommendations
  • Assess and revise SOPs based on feedback from data monitoring programs

• Non-Standard Flight Operations
  • Improve safety of non-revenue, non-standard flight operations

• Training Verification and Validation
  • Ensure flight crew training is verified by the operator
Recommended Safety Enhancements
Flight Crew Training

• Enhanced Upset Recovery Training, Including Approach-to-Stall
  • New approach-to-stall recovery procedures
  • Upset prevention & recovery, including unreliable airspeed

• Scenario-Based Training for Go-Arounds
  • Go-arounds for other than decision height
  • Complicating factors (trim, light weight, entry into clouds)

• Enhanced Crew Resource Management
  • Focus on pilot monitoring duties

• Training for Non-Normal Situations
  • Focus flying the airplane first
Recommended Safety Enhancements
Airplane Design

• Latest type designs from the four major airframe manufacturers include the following design features that mitigate ASA:
  • Low airspeed alerting / protection
  • Removal of invalid airspeed data from displays
  • Automatic pitot heat activation
  • Multi-sensory alerting of invalid air and inertial system data
  • Fault tolerant data source design
  • Connection of checklists to faults or malfunctions
  • Angle-of-attack / stall protection
  • Low speed protection or inhibiting of nose-up pitch trim

New Airplanes
- Low airspeed alerting
- Remove invalid airspeed from display
- Automatic pitot heat activation
- Multisensory alerting of invalid data
- Improved source data fault tolerant designs
- Connect conditions to checklist
- AOA protection
- Low speed nose-up trim protection/inhibit
Recommended Safety Enhancements
Airplane Design

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Recommended Safety Enhancements
Airplane Design

• Additional features for new designs to further mitigate ASA issues:

   - Thrust asymmetry compensation
   - Alert asymmetric thrust
   - Energy state symbology on PFD + Virtual day-VMC equivalent displays
   - Multisensory roll alert w/guidance
   - Bank / pitch attitude protection

New Airplanes

   - Low airspeed alerting
   - Remove invalid airspeed from display
   - Automatic pitot heat activation
   - Multisensory alerting of invalid data
   - Improved source data fault tolerant designs
   - Connect conditions to checklist
   - AOA protection
   - Low speed nose-up trim protection/inhibit

Feasibility (new design)
- High
- Med
- Low
Recommended Safety Enhancements
Airplane Design

• For new designs:
  • Continue incorporating features currently delivered on latest type designs, plus:
    • Bank angle protection on new fly-by-wire airplanes
    • Advanced bank angle alerting with recovery guidance
    • Virtual day-VMC displays with energy path guidance

At 35° bank...

At 45° bank...

• For existing designs: Study feasibility to implement and retrofit
## Recommended Safety Enhancements

### Coverage of ASA Themes and Events

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Recommended Safety Enhancements
Research

- **Flight Deck Systems (SE 207, 208)**
  - Effectiveness of angle-of-attack indicators/displays
  - Low energy state monitoring and alerting
  - Spatial disorientation detection and alerting
  - Improved display of automation states, including autoflight system disconnects and failures
  - Routine and non-routine use of autoflight systems, mode transitions, and autopilot/autothrottle disconnect

- **Simulator Fidelity (SE 209)**
  - Full stall modeling
  - In-flight validation of simulator-based training

- **Human Performance (SE 210, 211)**
  - Database of pilot responses to critical warnings and alerts
  - Training scenarios for attention issues
## Recommended Safety Enhancements

### Research Areas Addressed

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Recommended Safety Enhancements
Projected Risk Reduction

- Airplane Design
- Airline Operations
- Flight Crew Training

Risk Reduction

Projected Risk Reduction:
- ~60%
- ~55%
- ~50%

2013 2018 2025 2035

Fleet Demographics
Fatigue Risk Management Plans
Acknowledgements

Industry partners
• Airbus
• Airlines for America
• Air Line Pilots Association
• Alaska Airlines
• Austin Digital, Inc.
• Boeing
• Bombardier
• Compass Airlines
• Embraer
• Federal Express
• Honeywell
• Mitre
• Pinnacle Airlines
• Polar Air Cargo
• Rockwell-Collins
• Southwest Airlines

Government partners
• FAA
• NASA
• USAF
CAST SEs on SkyBrary:

Thank You