Loss of Control and Airplane State Awareness

Capt. Brit Etzold – The Boeing Company
COSCAP-NA/15
Xiamen, China
15 May 2015
Accident Categories
Change over time

Fatal Accidents – Worldwide Commercial Jet Fleet

Fatal Accidents – Worldwide Commercial Jet Fleet

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Airplane State Awareness Contribution

- External Fatalities [139]
- Onboard Fatalities [4269]
Airplane State Awareness Contribution

- **External Fatalities** [139]
- **Onboard Fatalities** [4269]
- **Attitude awareness** [674]
- **Energy state awareness** [596]*

* does not include Colgan 3407 or other turboprop accidents

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Fatal Events: 18, 17, 16, 3, 5, 2, 2, 2, 1, 7, 2
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
Kenya Airways 507 - Douala, Cameroon
Boeing 737-800 - May 5, 2007 - 114 fatalities

- 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 11°
- 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 35°, 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 45° 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 115° to the right, but is recovered to 70° right
- The FO states, “right captain, left, left, left, correction left.”
- Capt and FO are both on controls; Capt rolling right; FO rolling left

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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
Accident: West Caribbean MD-82 over Venezuela on 16-AUG-2005

Event Type: Loss of Energy Awareness
Injuries/Fatalities: 160 (152 PAX + 8 crew)
Flight: WCA 701
Local Time: ~2:00 am local time
Registration: HK-4374X
Phase of Flight: Cruise

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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Significant Themes

– Distraction
  – Attention management (e.g., channelized attention)
  – Decision-making (e.g., confirmation bias)

– Ineffective Alerting
  – No alert
  – Indirect or poorly timed
  – Salience
    • Not multisensory (e.g., visual only)
    • Inappropriate level (e.g., CAUTION rather than WARNING)
  – Nuisance alerts / false alarm rate
Significant Themes

- Lack of External Visual References
- **Crew Resource Management**
  - Communication
  - Monitoring
  - Authority gradient
- **Automation Confusion / Awareness**
  - Lost awareness of automation state
  - Failed to anticipate automation behavior
  - Autopilot trims or compensates
Significant Themes

- **Safety Culture**
  - Poor safety record
  - Operated with compromised safety barriers
  - Failures to coordinate with ATC
  - Influenced by time pressure
  - Crew pairing

- **Inappropriate Control Actions**
  - Direction opposite from that required to recover
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
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

Recommended Safety Enhancements

Fatigue Risk Management Plans

Airplane Design: ~50%
Airline Operations: ~60%
Flight Crew Training: ~55%

Projected Risk Reduction
CAST SEs on SkyBrary:

Thank You