Subject outline:

- Review of Aircraft Accidents
- Some Typical LOC-I Accidents
- Accident Investigations
- Coffin Corner
- Aerodynamic Stall and AOA indicators
- Developments in Flight Displays
- Aircraft Controllability
- Developments in Pilot Education and Training
- Cockpit Displays – Test and Evaluation
- Research on Primary Flight Displays and inclusion of AOA Indicator
- Conclusions
Review of Aircraft Accidents
Major Accidents by Decade

Worldwide Commercial Jets
1960 to 2009

<table>
<thead>
<tr>
<th>Decade</th>
<th>Major Accidents per million departures</th>
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<tbody>
<tr>
<td>60's</td>
<td>6.21</td>
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<tr>
<td>70's</td>
<td>2.42</td>
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<tr>
<td>80's</td>
<td>1.59</td>
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<tr>
<td>90's</td>
<td>1.18</td>
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<tr>
<td>2000's</td>
<td>0.57</td>
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Loss of Control Major Accidents
Commercial Jets
1999 through 2010

Source: Ascend, Boeing
Some typical LOC-I Accidents
Stall during high altitude cruise:

- West Carribean MD-82. Venezuela 2005 – high altitude stall («coffin corner») – climbed rapidly from 31,000 ft to 33,000 ft to avoid TS – altitude could not be sustained – on autopilot which gradually lifted the nose to hold altitude until AP disengaged and A/C entered a stall.

- Contributing cause factors: Let A/S drop to stall speed - improper stall recovery - A/C held with aft stick in deep stall with engine climb power until crashing – pilots confused.
Stall during high altitude cruise:

- Air France A330. South Atlantic 2009 - high altitude stall after loss of IAS (coffin corner) – A/C held with aft stick in a controllable deep stall with engine climb power until it crashed in the sea.

- Contributing cause factors: Lost A/S – not controlling attitude – allowed the A/C to stall – improper stall recovery – A/C held in deep stall and climb power – pilots confused.
Stall during Approach:

- Colgan Air DHC-8-Q400. Buffalo USA 2009 – stall during approach – went through stick shaker and pusher. Contributing cause factors: Improper stall recovery - overrode the pusher (by pulling) and entered a fatal spin to the right – pilots confused.


Stall during Approach:

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Stall during Approach:


The crash landing of Asiana Airlines Flight 214

July 6, San Francisco International Airport

- Pilot Lee Kang-Kuk, 46, had 43 hrs of training in control of a Boeing 777
- He had more than 9,000 hours total flying experience
- Pilot trainer Lee Jung-Min was newly qualified to instruct on a 777

3 Skids to a halt left of runway, passengers escape via emergency chutes before fuselage burns up

One victim found near wing

2 Plane flips up as it spins 360 degrees

One victim found near tail

Debris from sea wall found several hundred feet up the runway

Crash stages

1 Tail clips seawall

106 knots at impact

Target approach speed: 137 knots

One victim found near tail

4 Engine

5 Tail

6 Landing gear

Crash stages

1 Tail clips seawall

106 knots at impact

Target approach speed: 137 knots

112 knots at 125 ft (8s) Attempt to abort

103 knots at 3 seconds to impact Lowest speed

118 knots at 200 ft (16s)

134 knots at 500 ft (34s)

149 knots at 1,000 ft (54 seconds to impact)

Lower part of tail cone in rocks at sea wall

Significant part of tail in sea

Descent curve

Schematic, not drawn to scale

Toll: 2 killed 182 injured 123 escaped unhurt

Passenger nationalities

141 Chinese  77 South Korean  64 American  3 Indian  3 Canadian  1 Japanese  1 French  1 Vietnamese  3 others

Source: eyewitness accounts/video footage/photos/media reports/NTSB
Accident Investigations
Accident Investigations:
Historically, most LOC accidents are labeled «Pilot/Human Error»

- **Professor Dr. James Reason, 1997:**
  «The Organizational model views human error more as a consequence than as a cause. Errors are the symptoms that reveal the presence of latent conditions in the system at large»

- **Professor Dr. Sidney Dekker 2006, offers two views on HE,** :
  The Old View: «*Human error is a cause of trouble*» *(bad Apple Theory)*
  The New View: «*Human error is a symptom of trouble deeper inside a system*»

- **Dr. Simon Bennett, 2012:**
  "*Malfunctions are to be expected in aircraft, by virtue of their interactive complexity, tight coupling, and risk-and-error-prone operating environment. In the risk-laden world of aviation the pilot is the last line of defense*".
Accident Investigations:

- Historically, most LOC accidents are labeled «Pilot/Human Error».

- In modern accident investigation theory Human Error is not considered a cause of accident, but a symptom of systemic weakness.

- LOC accidents are considered «Organizational Accidents» and have several underlying cause factors.
Coffin Corner
Coffin Corner

![Diagram showing velocity and altitude relationship with color-coded lines for V_min, V_max, and V_cruise.]
Aerodynamic Stall and AOA indicators
Aerodynamic Stall

Stall can occur when performing a variety of maneuvers.

- The wing does not know about airplane attitude or airspeed.
- The deciding factor is the critical/stall angle of attack.
- The wing stops flying when the stall angle of attack is exceeded.

Result = Stall (and possible LOC)

Required = Angle of Attack Indicator

Deep Stall
Aerodynamic Stall

[Diagram showing LIFT vs. Angle of attack, with critical angle of attack and stall warning indicated.]
Stall recovery:

JAR 25 CS: « As soon as the aeroplane is stalled, recover by normal recovery technique.»

What is normal recovery technique?

UK CAA: “Simultaneous pitch down and full power”

FAA: “Unstall, smoothly increase power to increase airspeed and minimize loss of altitude”

NTPS: “Unstall, let airspeed increase to at least 1.2Vs before increasing power, recover” (or, “unstall, delay power for 2 sec and increase power in 2 sec, recover”).
Boeing:

"Emphasis during recovery should be to immediately reduce angle of attack and return the aircraft to a safe flying condition".

"Reducing angle of attack as the first and most important response in the recovery".

Airbus:

"Apply nose down pitch control to reduce AOA".

"Tests show that while applying full thrust at stall warning while maintaining altitude can contribute to reaching full stall conditions" (Ref. AF447).

"Civilian pilots, and even turboprop military pilots, are not familiar with high Mach buffet".

"Stall recovery training is possible in FFS."
Some aircraft are equipped with artificial stall warning (shaker) and artificial stall break/nose drop (pusher).

In US NAVY AOA has been in use since the early jet days. Ex A-4 A-7 etc

In USAF AOA was introduced in some «difficult» A/C types during 1950-ies, ex. F-104.

Later A/C has AOA, ex. F-16.

During stall training with «pusher» A/C, activation of «pusher» is the artificial «stall» which must trigger recovery action.

More accurate flying by AOA. We may control A/C by using AOA. Indicated Airspeed (actually EAS) is just an aerodynamic reference associated with airloads.
F-16A AOA
A-10C AOA

Trim Nose Up Some More
170(ish) KIAS

AoA Indicator

Trim Hat
TYPICAL AOA INDICATORS
Developments in Flight Displays
TYPICAL FLIGHT DISPLAYS - 1950’s
CF-104 - 1960’s
Basic T
C-47 1940’s – 50’s – 60’s
COMMERCIAL AIRLINER 1970’s

Basic T
GLASS COCKPIT – VERTICAL TAPE – 1980’s

Basic T
ROUND DIAL AND POINTER – PRE 1980’s

VERTICAL TAPE – POST 1980’s
USAF AIRSPEED MACH INDICATOR – 1960’s

Figure 3-10. Airspeed-Mach Indicator (AMI)

1. Command Mach Marker
2. Airspeed Warning Flag
3. Airspeed Scale
4. Maximum Allowable Mach Marker
5. Command Airspeed Marker
6. Command Airspeed Readout Window
7. Command Mach-Readout Window
8. Command Airspeed Slowing Switch
9. Command Mach Slowing Switch
10. Acceleration Readout Window
11. Zero Angle of Attack Symbol
12. Fixed Index Line
13. Final Approach Symbol
14. Mach Scale
15. Angle of Attack Scale
16. Minimum Safe Speed Symbol
17. Acceleration Scale
USAF SR-71A INSTRUMENT PANEL – 1960’s – 70’s – 80’s
FUTURE PFD’s – CIRRUS PERSPECTIVE – 2013 + ?
AIRBUS PFD’s – 1980’s – 2010’s + 30 YEARS?
BOEING PFD’s 2010’s + 30 YEARS?
CYBERJET SJ 30 PFD’s - 2013
AGUSTA WESTLAND AW 101
SIKORSKY S-92A – 2005 - ?
Aircraft Controllability
Pilot Information Cueing Channels

- Auditory
- Peripheral Visual
- Central Visual
- Tactile

PILOT
The Series Pilot Model
Basic Pilot Knowledge?

\[ R/C = (T - D)V/W \]

\[ R/D = (D - T)V/W \]
Developments in Pilot Education and Training
Attitude Instrument Flying – 1940’s - ?
Instrument Categories – 1950’s - ?

Figure 7-2.
Instrument Categories:
Control-Performance-Navigation
Instrument Cross Check Technique – 1950’s - ?

1 MAINTAIN INDICATIONS CONSTANT

2 OBSERVE — to detect any deviation

3 DEVIATION DETECTED —- 4 ADJUST

6 MONITOR— to insure indications changed as desired

5 ADJUST attitude, power, or both
Aircraft Control Fundamentals:

- Pitch controls Airspeed
- Power controls Energy (Accel -R/C-R/D)

\[ R/C = (T - D)V/W \]

\[ R/D = (D - T)V/W \]
Factors Influencing Cross Check Technique
«Chasing the Performance Instruments»

A direct control response to the PERFORMANCE INSTRUMENTS without proper reference to the CONTROL INSTRUMENTS may result in useless chasing of instrument indications.

Predetermine definite indications to be held or established on the CONTROL INSTRUMENTS.
Recommended Instrument Cross Check Technique?
Universal Avionics PFD – 2010’s + ?
Rockwell Collins Proline Fusion – 2013 - ?
Enhanced Flight Vision System HUD
"The Big Picture" (Proposed 1990)

'Big Picture' — one large electronic display screen. The pilot uses touch, voice and helmet pointing to indicate, select, command and initiate modes, functions and actions.

1. On the upper area of the screen the pilot sees head-up display (HUD) and weapon aiming symbols and alphanumericics superposed on the view of the real world. At night or in poor visibility low light television or infra red views are used.

2. Television or infra red sensors produce a view below the nose of the aircraft.

3. The sides of the display are used to present systems information such as fuel, engine, communications and weapon 'stores'.

4. HUD symbols and alphanumericics.

5. Pilot's visor used for pointing.

Presentation of information so as to appear three-dimensional. Another attribute is the opportunity it affords the pilot of selecting a different 'point of view'. For example the computer-generated view of the world can be seen as if from a position behind the aircraft. As with some video computer games, the pilot can fly his aircraft against the 'background' of sky and ground. The pilot might even take a position to one to the 1930s such an idea was viewed with some concern by some pilots because the overall technology of aviation within their experience was limited. Today the most recent generation of pilots and those about to take up flying live in a vastly different world: a world in which they have come to accept the abilities and reliability of the computer. Therefore they do not expect to have controls directly connected to the
Cockpit Displays – Test and Evaluation
“There have been a number of papers and articles written about operational difficulties with modern display and other cockpit systems. As we see it, the problem has been a series of discontinuities between the users and the designers, between the designers and the testers, and between the users and the testers.

“The display design must consider why the pilot needs the data and what the pilot is expected to do with the data. According to Singleton, several questions must be answered during development of a display:

- Does the pilot’s need justify the display?
- What data does the pilot need that has not been provided?
- Can the average pilot obtain what is required easily?
- Does the display conform to the real world?
- To other cockpit displays?
- With previous pilot habits and skills?
- With required decisions and actions?”
Research on Primary Flight Displays and inclusion of AOA Indicator
Mean subjective ratings for the 5 altitude and airspeed display formats. A rating of "1" was very favorable and "5" was very unfavorable.
Figure 6 – moving horizon pitch ladder AI².

Figure 7 – asymmetric attitude reference AI display².

Figure 5 – PFD with ADI in arc-segmented attitude reference (ASAR) display format, as used for UA recovery research in the Harvard².
Research results 2002-2004

Figure 11 – average reaction time for each of the three ADI displays, summed for all six entry manoeuvres and subject pilots².

Figure 12 – control reversal errors, for each type of ADI display².
Conclusions

- Several recent LOC accidents indicate that the human factor related aspects of primary flight displays, lack of AOA displays, flight control design, and pilot education and training, play a significant role in the pilots handling of an aircraft.

- It is recommended that the industry initiate more human factor based research within these areas.

- The author suggest that SETP should get more involved in human factor focused development, simulator and flight experiment, and flight testing of new types of PFD.
Thank you for your attention

Questions?