Dedicated to innovation in aerospace

Angle Of Attack
Do we need AOA indications in transport aircraft?

LOC-I Salzburg, November 19, 2012

Arun Karwal

Summary

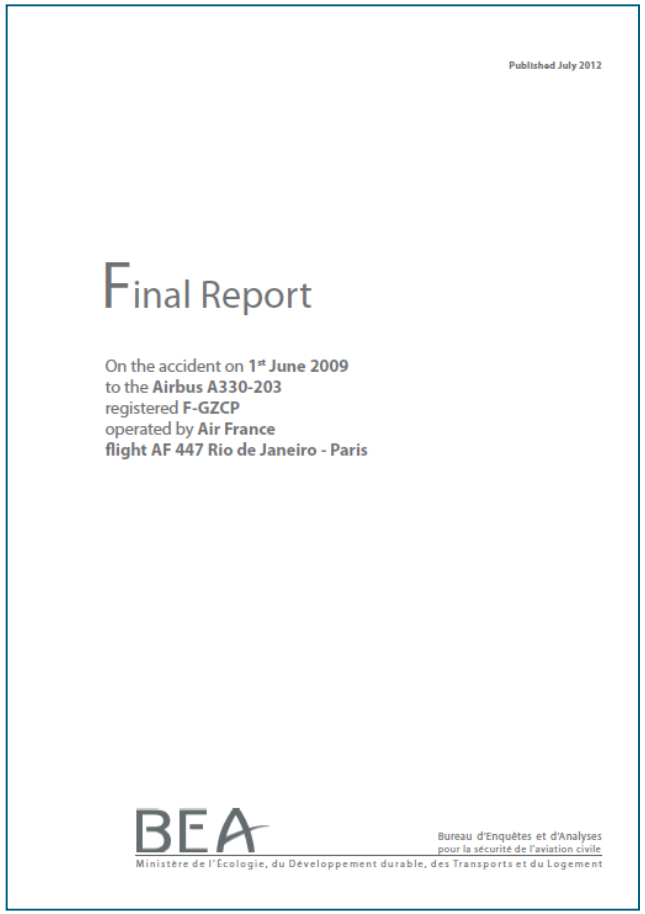
- **Rationale for research**
- **Examples of AOA presentation in civil flight decks**
- **Experiment design**
- **Simulator**

Rationale for Research

Landmark recent stall accidents

- **ANZ D-AXLA, A320 Perpignan, November 2008**
- **Colgan Air 3407, DHC-8, Buffalo, February 2009**
- **Turkish Airlines 1951, B737, Amsterdam, February 2009**
- **Air France 447, A330 GIG-CDG, June 2009**
- **Gulfstream, G650 N652GD, Roswell, April 2011**

BEA AF447 Final Report

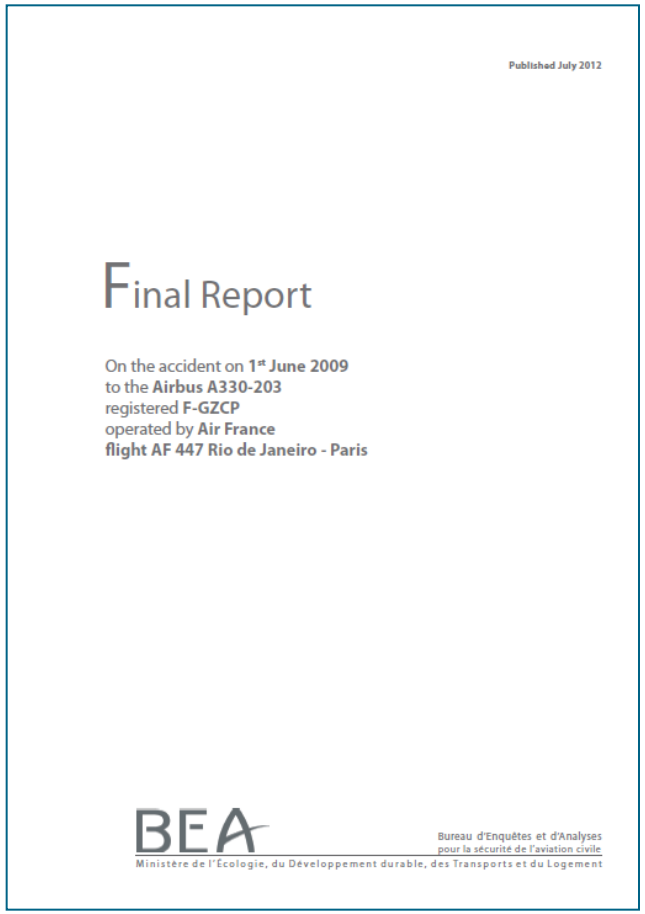


4.2.2 Recommendation relating to Certification

Angle of Attack Measurement

The crew never formally identified the stall situation. Information on angle of attack is not directly accessible to pilots. The angle of attack in cruise is close to the stall warning trigger angle of attack in a law other than normal law. Under these conditions, manual handling can bring the aeroplane to high angles of attack such as those encountered during the event. It is essential in order to ensure flight safety to reduce the angle of attack when a stall is imminent. Only a direct readout of the angle of attack could enable crews to rapidly identify the aerodynamic situation of the aeroplane and take the actions that may be required.

BEA AF447 Final Report



Consequently, the BEA recommends:

That EASA and the FAA evaluate the relevance of requiring the presence of an angle of attack indicator directly accessible to pilots on board aeroplanes.

Examples of AOA presentation in civil flight decks

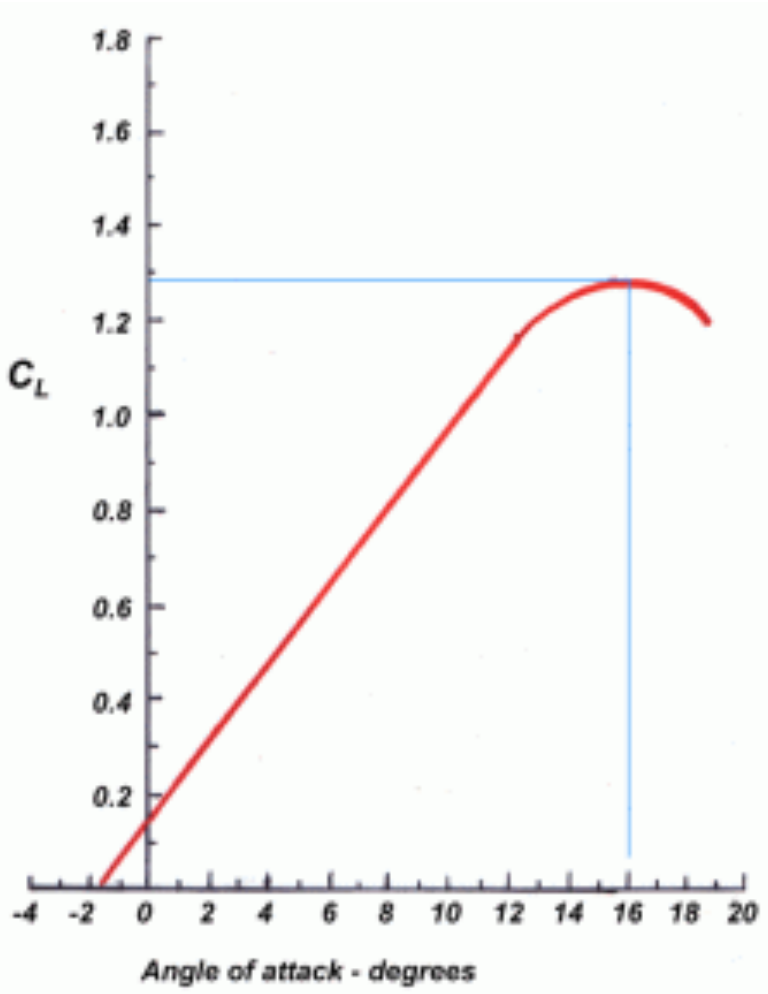
Stall: AOAmax versus Vs

AOAmax

- Flaps/slats
- Mach
- Ground Effect
- Wing contamination

Vstall (Pitot tube)

- Flaps/slats
- Mach
- Ground Effect
- Wing contamination
- Load factor
- Weight
- C.G.



High AOA warning (W) and prevention (P) devices

- Stick shaker (W)/pusher (P)
- Envelope protection (P)
- Speed stability (P)
- Aural warnings (“STALL STALL STALL”, tones) (W)
- EFIS: speedtape, PLI/AOA-margin (W)
- AOA indexer (W)

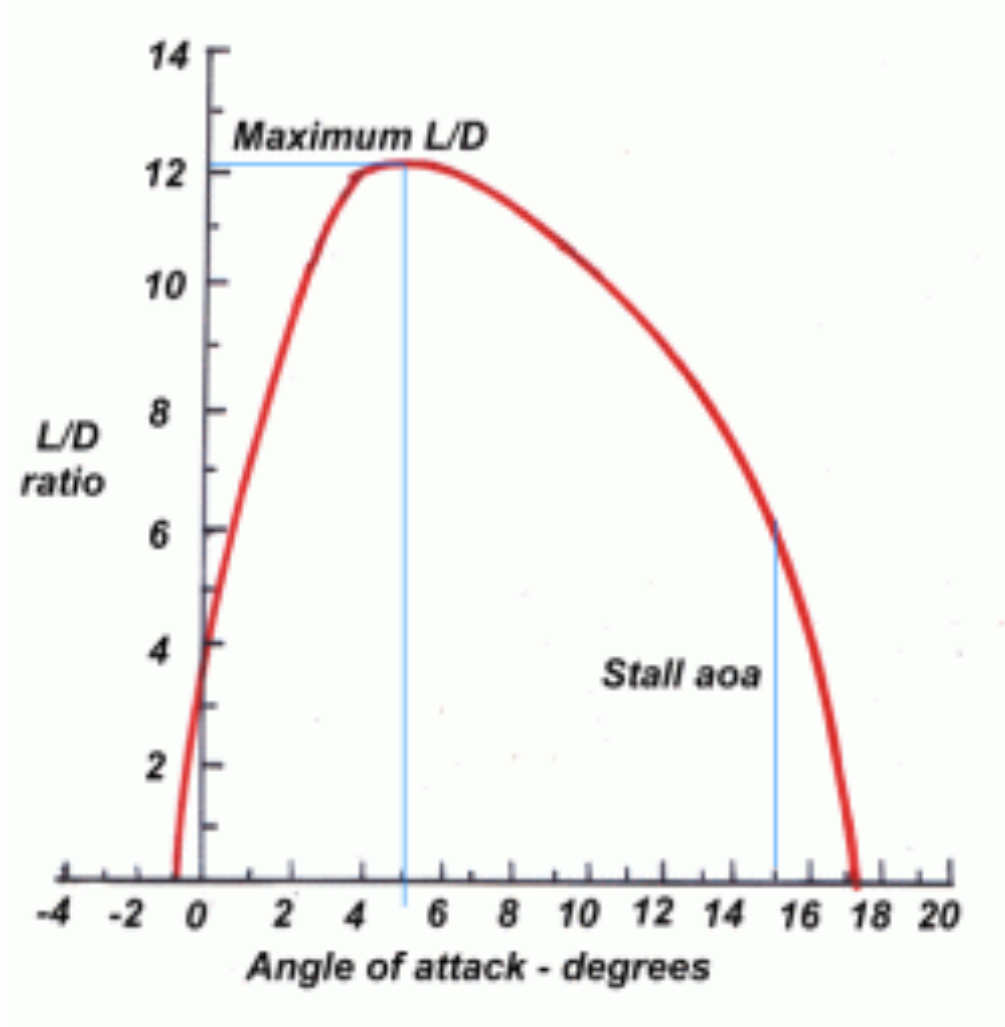
Use of AOA for flight path optimization ?

Parameters

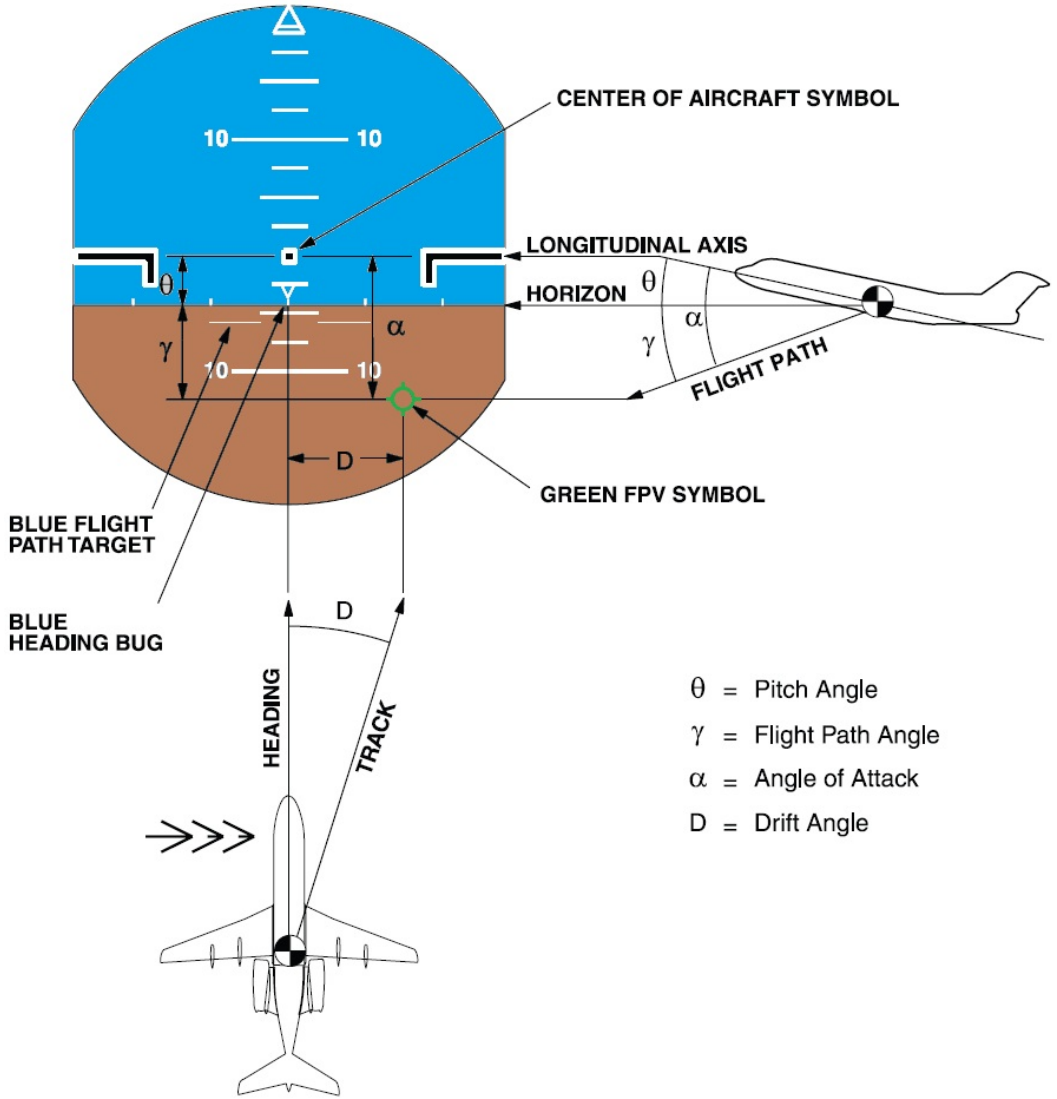
- Vx (Best Angle)
- Vy (Best Rate)
- Long Range Cruise Speed
- Holding Speed

can be expressed as an AOA independent of actual weight

- Weight entry errors can be detected
- Simple to use, no reference to tables

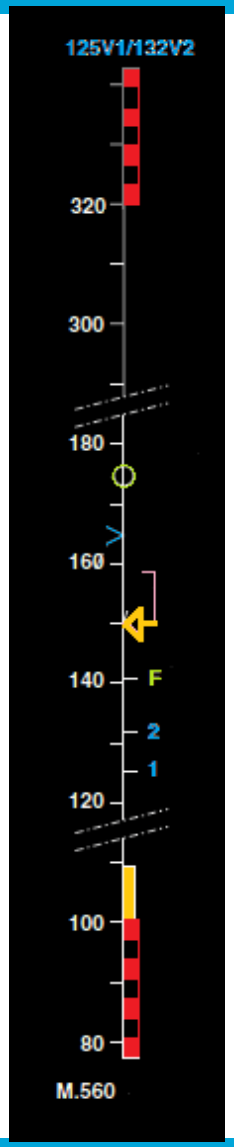


Examples of AOA indications (1)



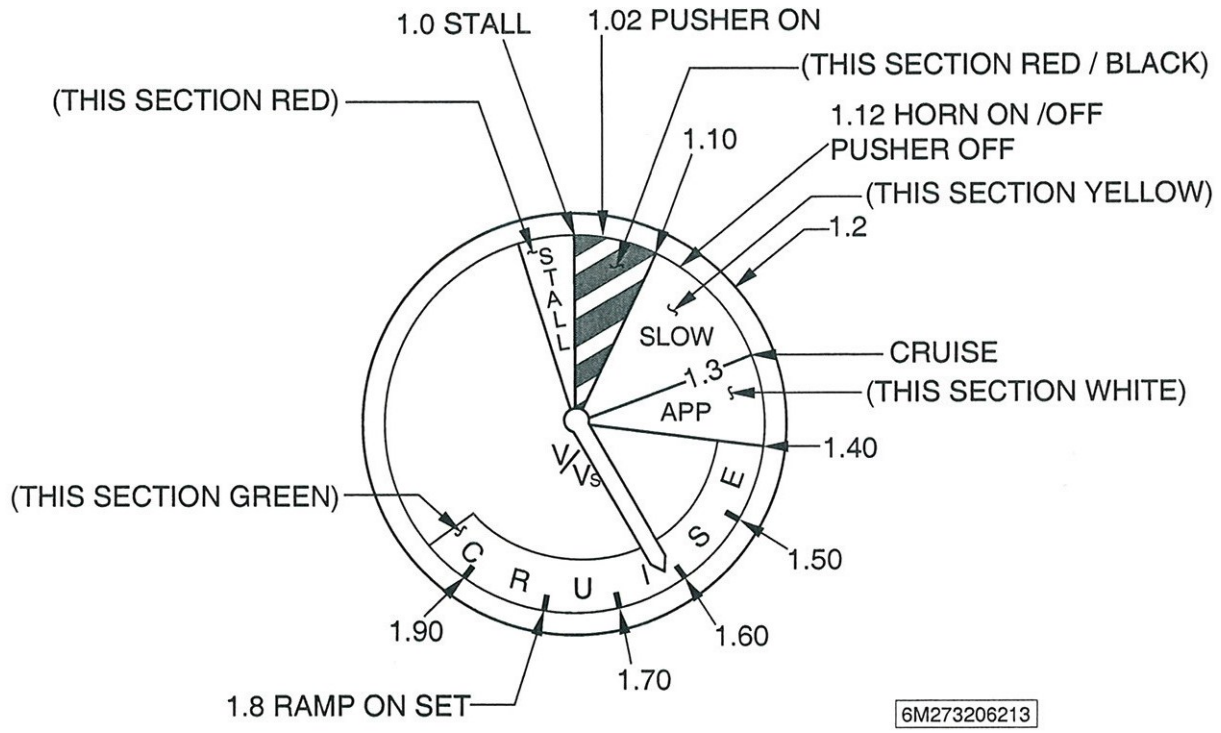
AOA = Pitch Angle - FPA

Examples of AOA indications (2)



Difference between actual speed and Vss is an indication of AOA

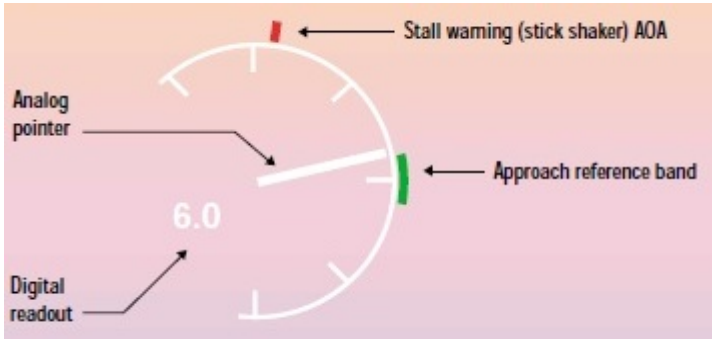
Examples of AOA indications (3)



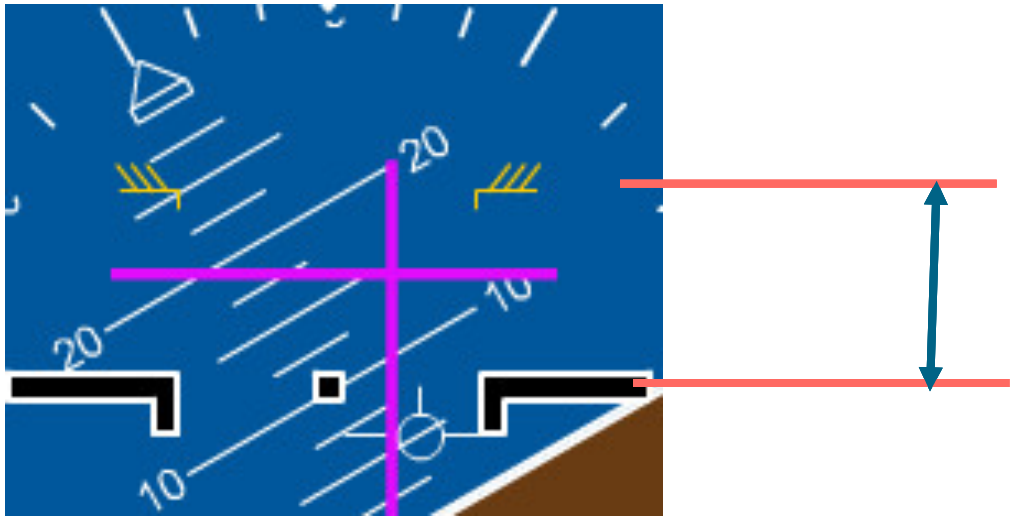
Examples of AOA indications (4)

Examples of AOA indications (5)

Boeing AOA index (option on PFD)



Examples of AOA indications (6)

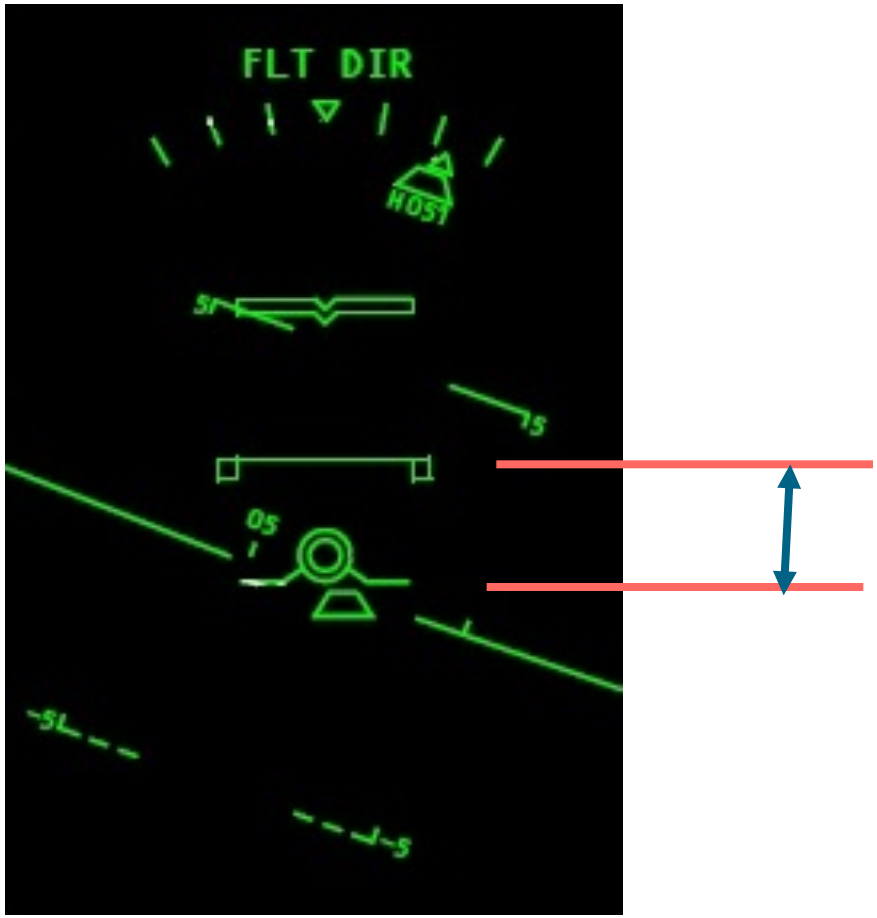


AOA margin to Pitch Angle

Pitch Limit Indicator (PLI, Boeing)

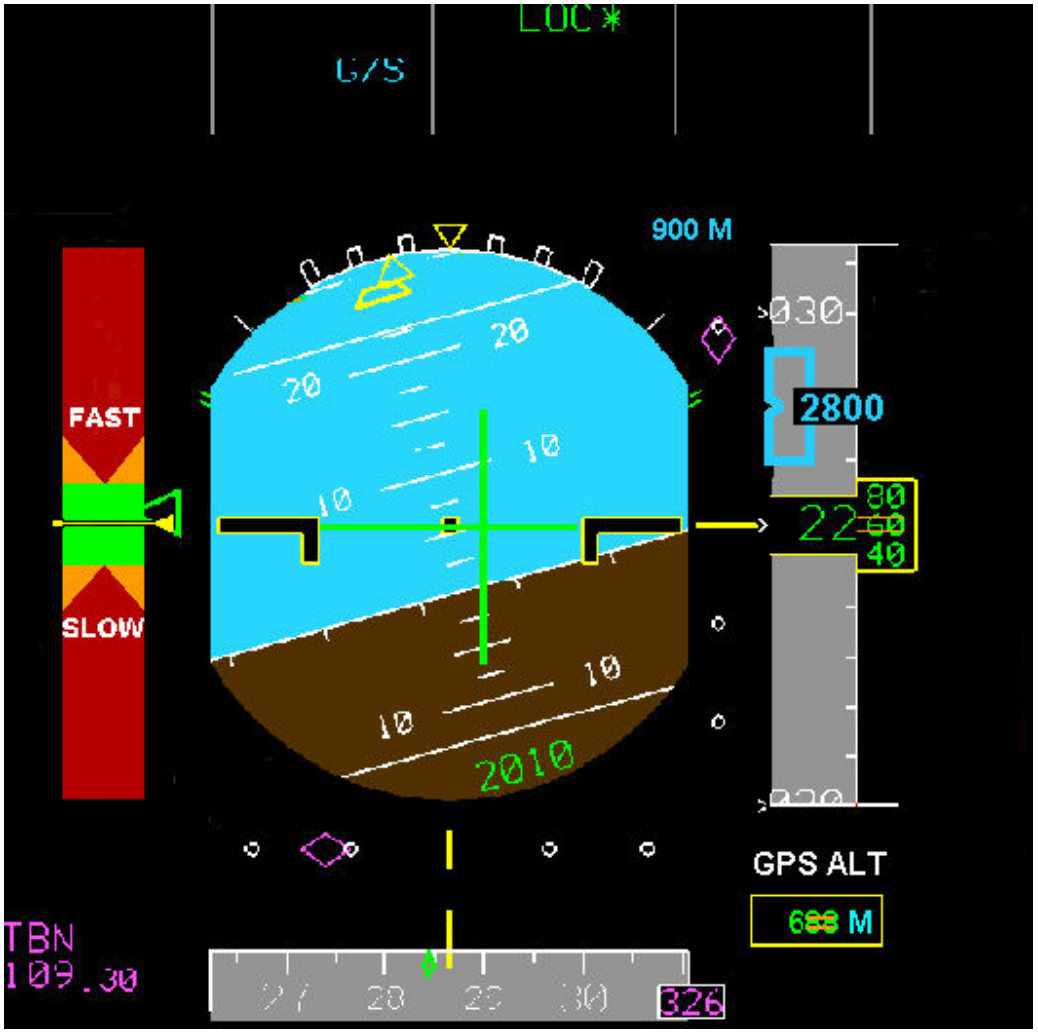
AOA Margin Indicator (AMI, Fokker WINDSHEAR option)

Examples of AOA indications (7)



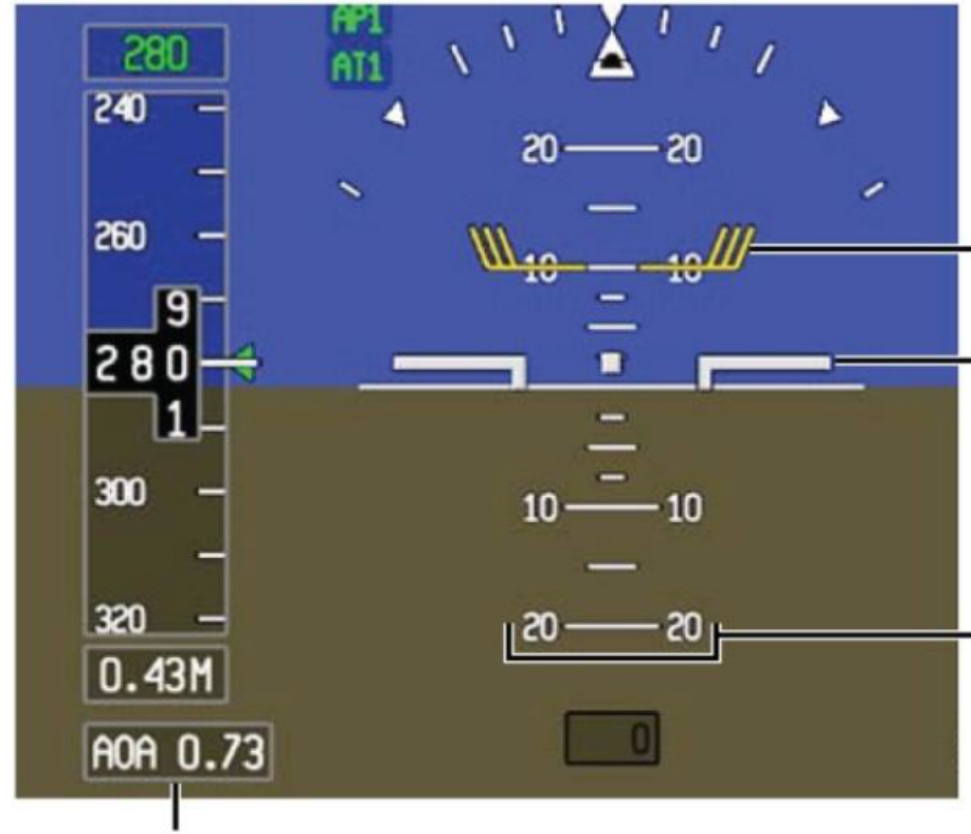
AOA margin to FPA (B787 HUD)

Examples of AOA indications (8)



Airbus Back-Up Speed Scale (BUSS) option replaces the normal PFD speed- and altitude tapes with AOA and GPS ALT when all ADRs are switched OFF.

Examples of AOA indications (9)



Pitch limit indicator

Airplane symbol

Pitch scale (in degrees)

Normalized AOA readout

Experiment design

Why AOA on the flight deck?

- **Positive AOA control, rather than speed- or pitch control**
- **Critical flight conditions with reduced stall margin**
  - UNRELIABLE AIRSPEED
  - WINDSHEAR
  - TERRAIN ESCAPE
  - UPSET RECOVERY
  - STALL RECOVERY
- **Optimize flight profile (Best Angle, Best Rate)**
- **Detect weight entry errors voor approach**

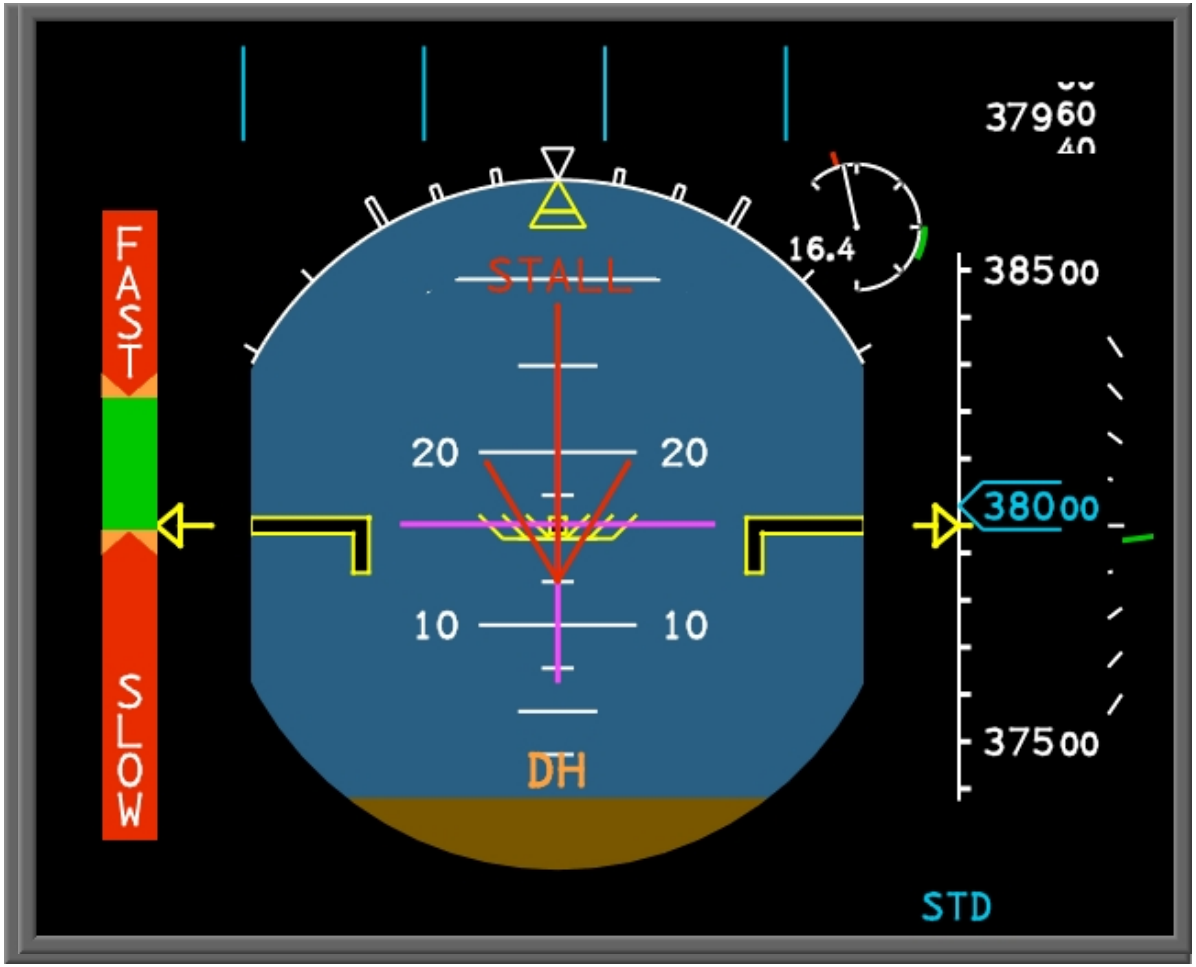
Design and validation

- **Research objective: Make recommendations**
  - Under which circumstances adding AOA information is useful
  - On what display elements give the best performance
- **Simulated trials**
  - Phase I : Expert sessions, definition of test matrix
  - Phase II: User sessions, data gathering

Test matrix

- **Scenarios**
  - Upset recovery
  - Windshear recovery
  - Icing
  - Stall recovery at low altitude
  - Stall recovery at cruise altitude
  - Unreliable airspeed (pitot tube blockage)
- **Display elements**
  - Fast/Slow indicator versus speed indication
  - Absolute versus normalized AOA indication
  - Integrated display elements versus stand-alone indicator
- **No/Minimal impact on existing procedures**

Examples of display elements (Fokker JetLine)



Issues to be addressed

- **Protection of intellectual property: some display elements are patented**
- **Sensor accuracy**
- **Conflicting information**
- **Impact on existing procedures**

- **In-depth analysis is considered out-of-scope…**

Simulator

Simulated trials

- **High Fidelity simulation in NLR Generic Research Aircraft Cockpit Environment (GRACE)**
  - Motion
  - Realistic environment
  - Realistic scenario
  - Yoke or sidestick

GRACE November 2012

GRACE November 2012

Current planning

- **NOV 2012 – Acceptance of new visual system**
- **DEC 2012 – Phase I AoA trials**
- **FEB-MAR 2013 – Phase II AoA trials**
- **APR 2013 – Recommendations to the community**

➔ Your input is highly appreciated !

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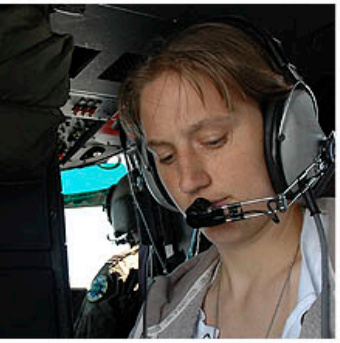




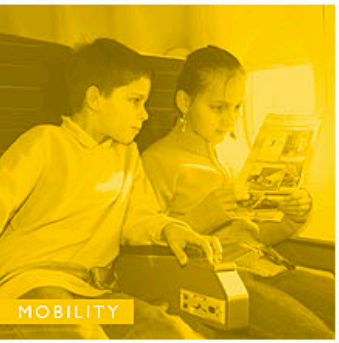

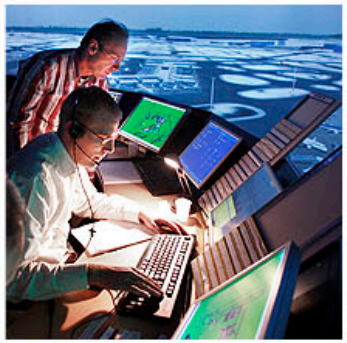


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