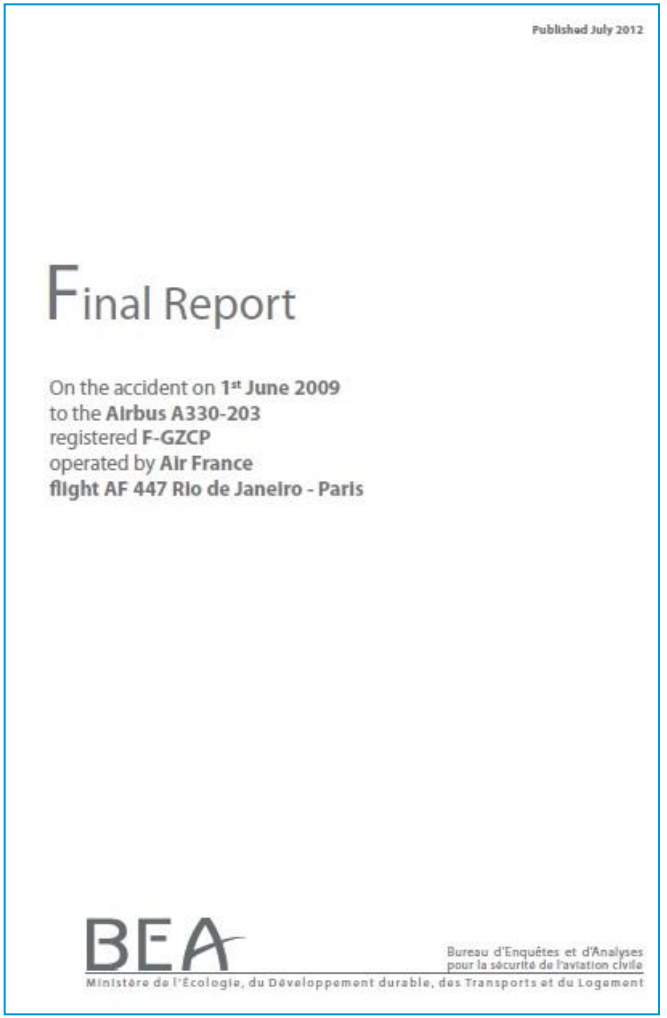
Dedicated to innovation in aerospace

Angle-of-attack display in modern commercial aircraft
Do we need that?

ICAO LOC-I Symposium, Montréal 20-22 May 2014

Arun Karwal (National Aerospace Laboratory NLR)

Rationale



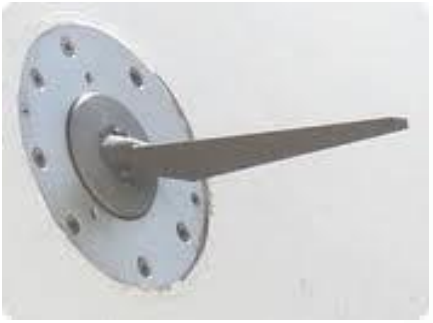
"Consequently, the BEA recommends:

- *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."*

Stall: AOAmax versus Vs

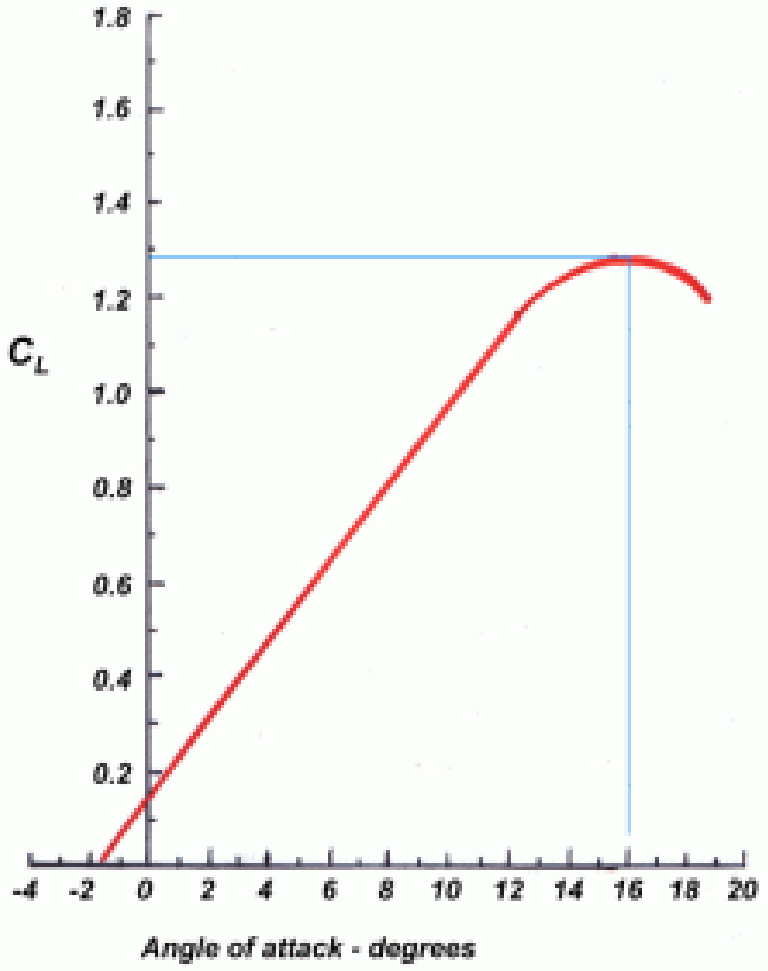
AOAcrit (vane, IRS)

- Flaps/slats
- Mach
- Wing contamination



Vstall (Pitot tube)

- Flaps/slats
- Mach
- Wing contamination
- Nz
- Weight
- C.G.



High AOA warning and prevention devices

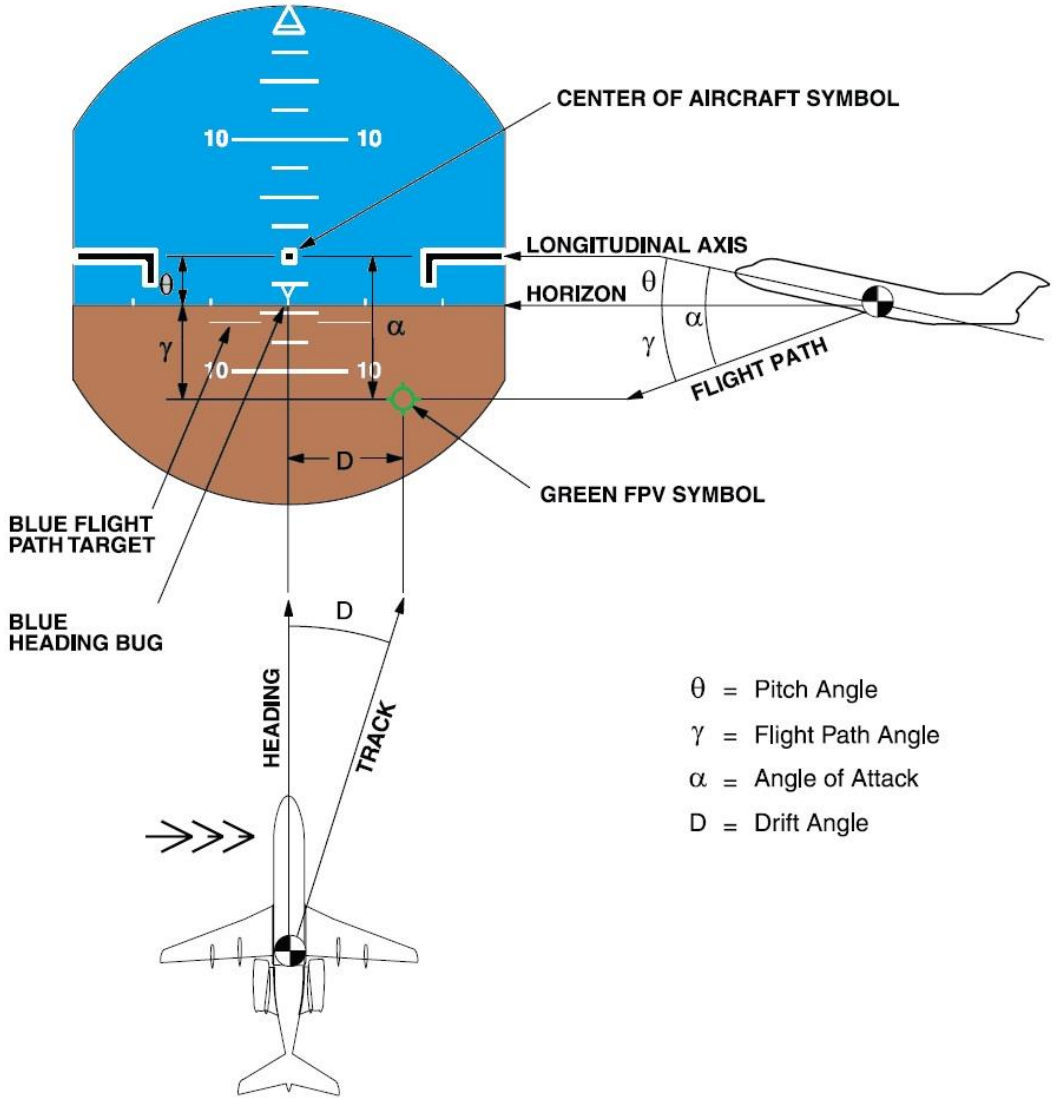
- **Stick shaker (W)/pusher (P)**
- **Envelope protection (P)**
- **Speed stability (P)**
- **Aural warnings (W)**
- **Visual indications on PFD (W)**

Sec. 25.207 — Stall warning.

(a) Stall warning with sufficient margin to prevent inadvertent stalling [...] must be clear and distinctive to the pilot in straight and turning flight.

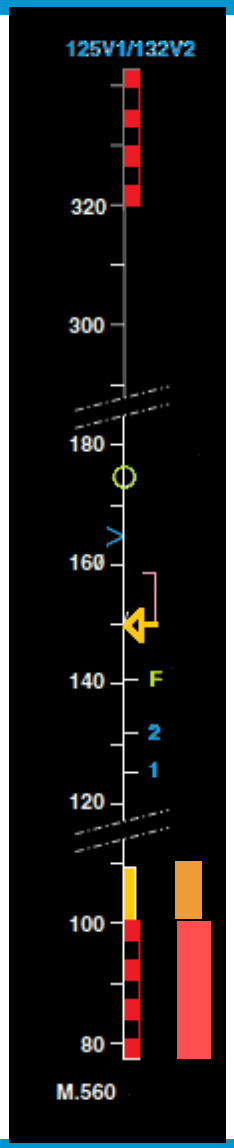
	CAUTION-level	WARNING-level
ASAS	"TRAFFIC"	"CLIMB"
TAWS	"TERRAIN"	"PULL UP"
Stall warning	...	...

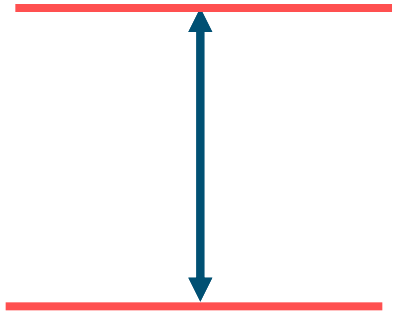
AOA on the flight deck: PFD



AOA = Pitch Angle - FPA

AOA on the flight deck: speedtape



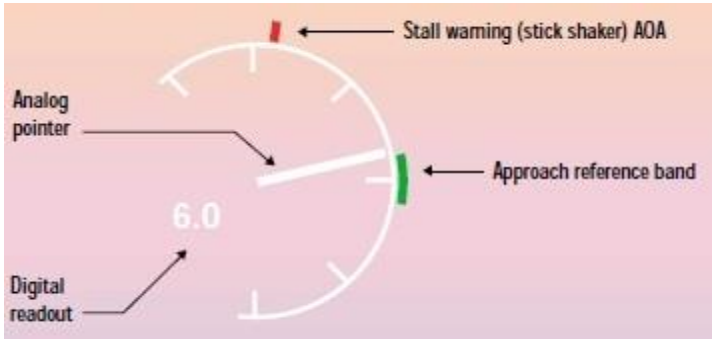


Distance between actual speed and minimum speed is indication of AOA

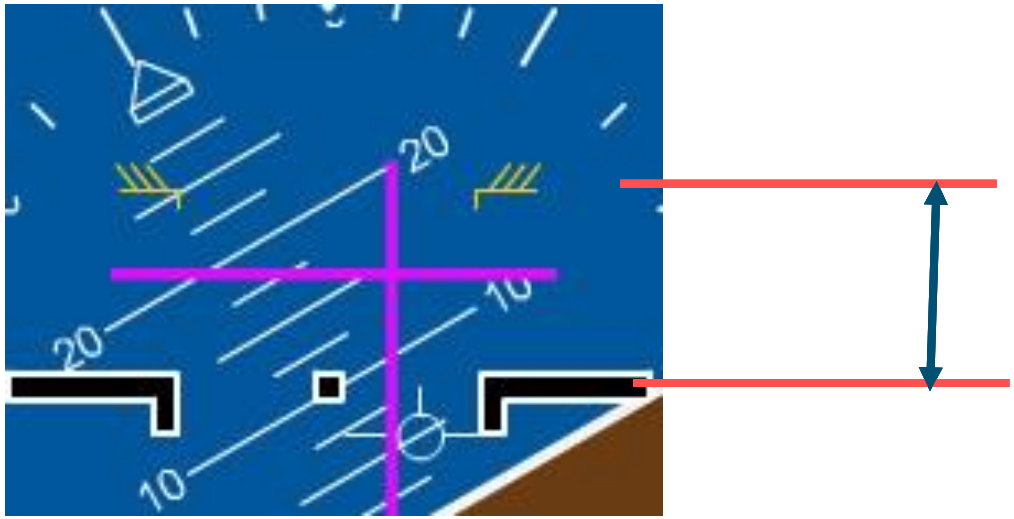
AOA on the flight deck

AOA on the flight deck

AOA index



AOA on the flight deck: PLI

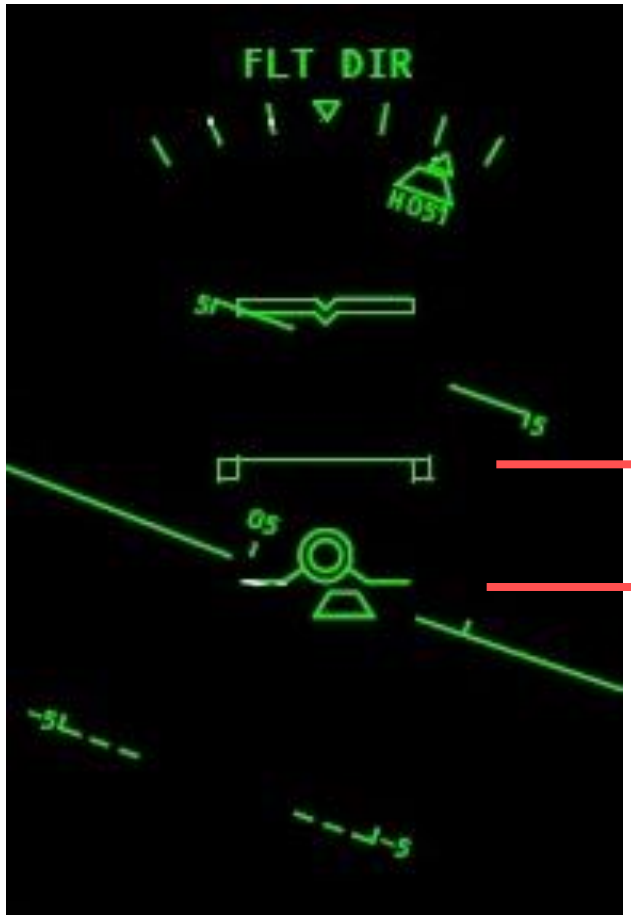


AOA margin w.r.t. Pitch Angle

“Pitch Limit Indicator” (Boeing)

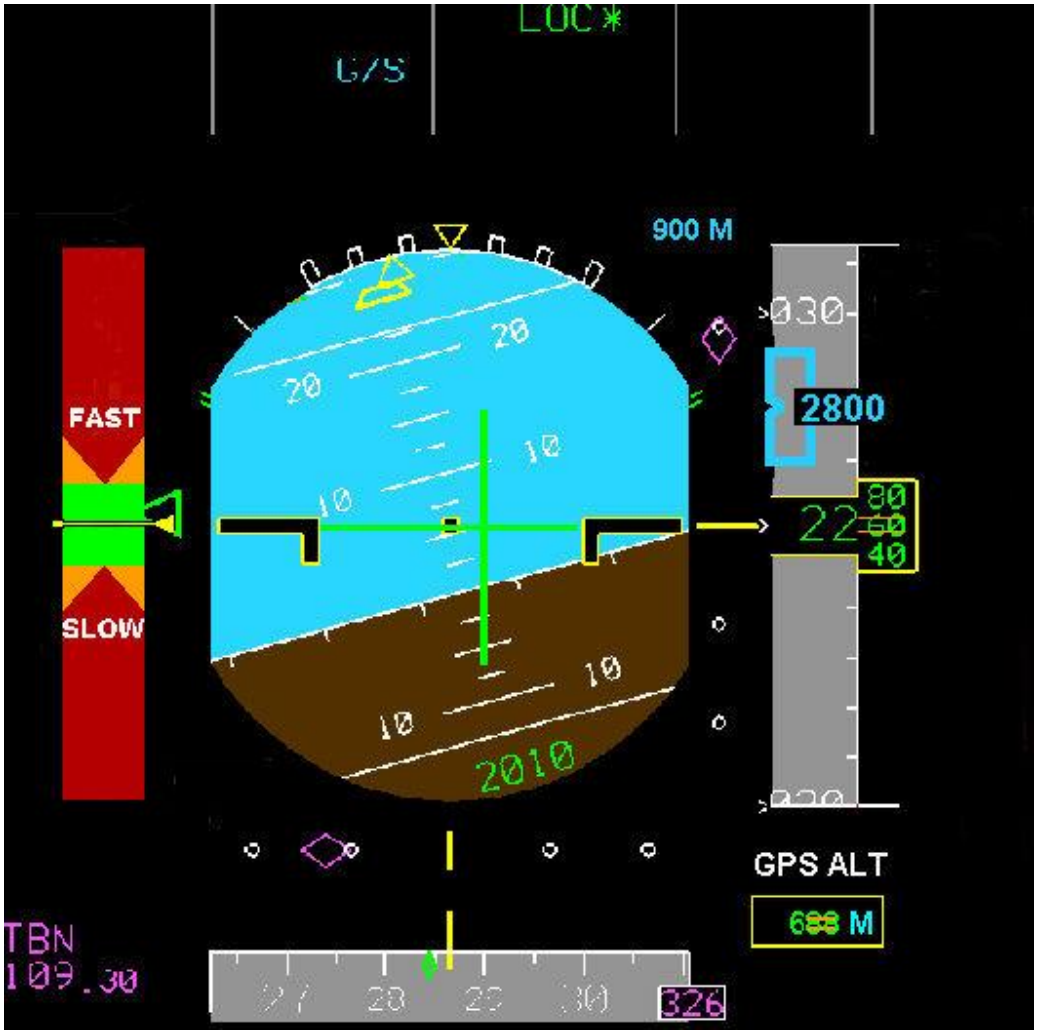
“AOA Margin Indicator” (Fokker, part of WINDSHEAR option)

AOA on the flight deck



AOA margin (FPA)

AOA on the flight deck: BUSS



BUSS option replaces the normal PFD speed- and altitude tapes with AOA and GPS ALT when all ADRs are switched OFF.

NLR Research

Angle-of-attack display in modern commercial aircraft
Do we need that?

1. **Display analysis (EID based on SRK Model, TU Delft)**
   - Display Type 1: AOA indicator
   - Display Type 2: Pitch Command
   - Display Type 3: AOA display on the speedtape

2. **Accident/incident review using the SRK Model**

3. **Simulator experiment (15 crews)**
   - Scenario 1: Upset Recovery
   - Scenario 2: Unreliable Airspeed
   - Scenario 3: Low Altitude Stall
   - Objective and subjective data captured

SRK Model (Rasmussen)

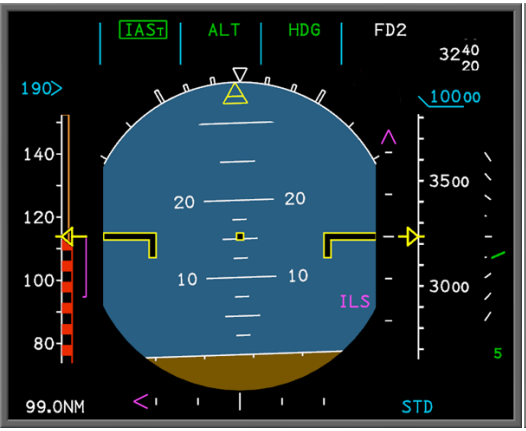
- **Skill Rule Knowledge (SRK) Model of Behavior Types**

  - A skill-based behaviour represents a type of behaviour that requires very little or no conscious control to perform or execute an action once an intention is formed; also known as a *sensorimotor* behaviour.

  - A rule-based behaviour is characterised by the use of rules and procedures to select a course of action in a familiar work situation.

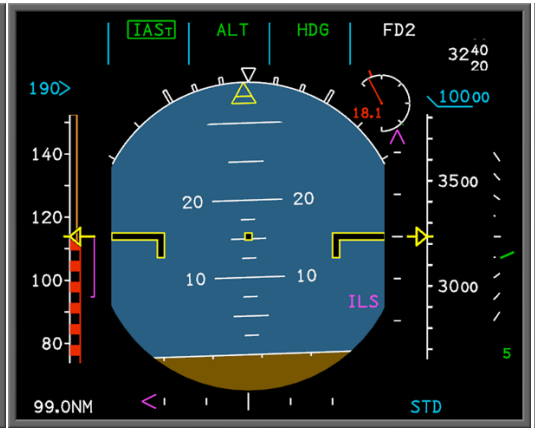
  - A knowledge-based behaviour represents a more advanced level of reasoning. This type of control must be employed when the situation is novel and unexpected.

Experiment display types



Baseline PFD

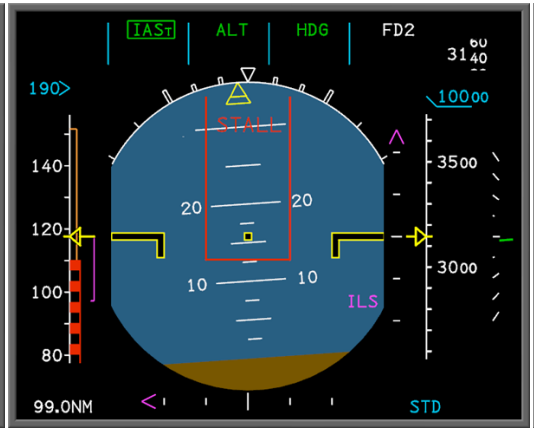
Speedtape with low speed cues and pitch ladder with pilot-selectable FPV.



Type 1
Separate AOA indicator

Indication with AOAmax and approach reference

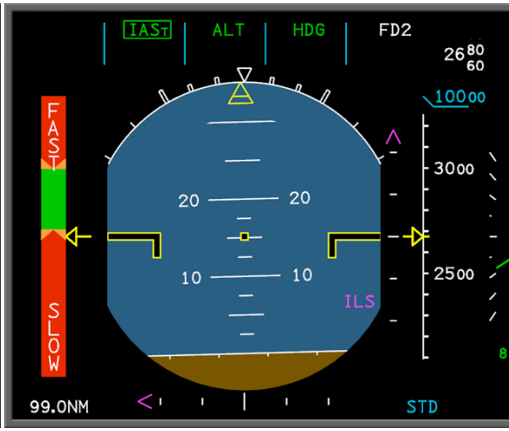
KNOWLEDGE



Type 2
Pitch guidance

"TCAS" box symbology for (approach to) stall guidance

RULE



Type 3
FAST-SLOW

FAST/SLOW indication replaces speed tape.

KNOWLEDGE

Piloted Study results

Scenario 1: Upset recovery

Scenario 2: High altitude UNRELIABLE AIRSPEED

Scenario 3: Landing configuration low altitude stall

- **Objective data:**
  - No difference between Baseline and AOA-indicator (Type 1).
  - Bucket-type increases recognition of reduced AOA margin in UNRELIABLE AIRSPEED scenario.
  - Bucket-type performs marginally better in LOW ALTITUDE STALL scenario.

- **Subjective data:**
  - Statistically significant result in PERFORMANCE and WORKLOAD ratings: Bucket > AOA > Baseline

Findings

- From the incident/accident review: stall incidents/accidents show a high percentage of mishaps at the RULE BASED level.
- A separate AOA indicator provides information on a KNOWLEDGE level, and is (therefore) of little/no use in an (approach to) stall scenario.
- A RULE BASED cue, that indicates WHAT TO DO increases their ability to recognize an (approach to) stall condition, increases performance and reduces workload.

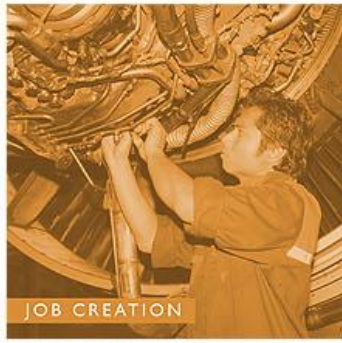
So…

- **Do we need an AOA indicator?**
  - Probably not. But the indications and warnings leave room for improvement.
    1. Build-up
    2. Harmonization of onset criteria and aural and visual indications.

	CAUTION-level: KB	WARNING-level: RB
ASAS	"TRAFFIC"	"CLIMB"
TAWS	"TERRAIN"	"PULL UP"
Stall warning	"STALL" (?)	"PUSH" (?)

Dedicated to innovation in aerospace




www.nlr.nl - info@nlr.nl