Angle of Attack Indicators: Can They Help?

Dai Whittingham
UK FLIGHT SAFETY COMMITTEE

IASS 2019 – Taipei – 5 Nov 2019

This is not about:

- B737 MAX
- Air France 447
- Boeing
- Airbus
- Any other manufacturer
- Any regulators
- Any region or nation

This is about:

- Angle of attack displays
- Exposing the arguments
- Limitations
- Advantages/disadvantages
- Training

Stall warnings in high capacity aircraft: The Australian context

(ATSB Aviation Research Report AR-2012-172)

- 245 stall warnings or stall warning system events in 5 years
- 70% genuine warnings of approaching stall
- 33 serious/high risk incidents

"To avoid higher risk stall warning events, pilots are reminded that they need to be vigilant with their awareness of angle of attack and airspeed, especially during an approach on the limits of being stable."

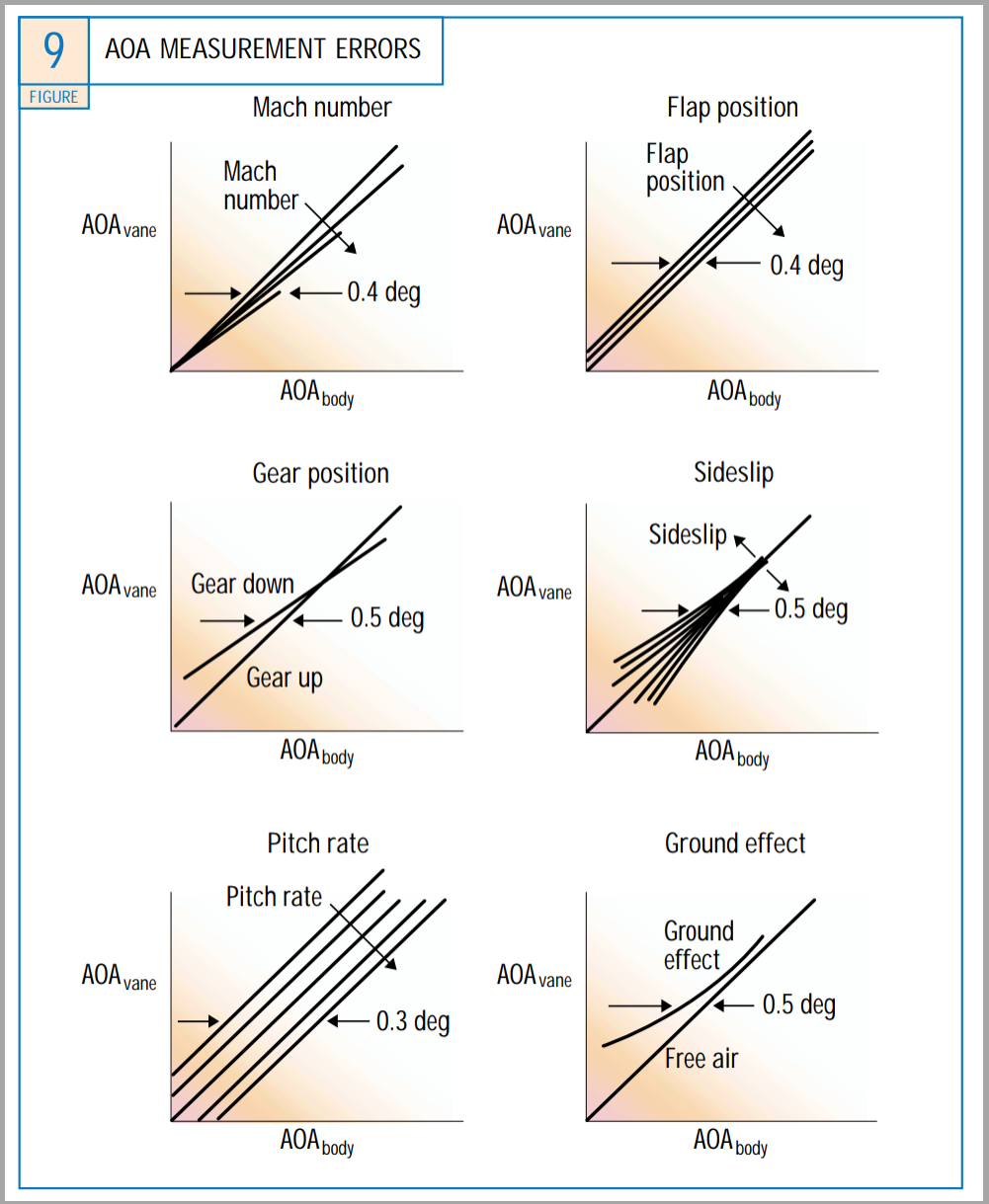
Opinions about using AOA…

Military?

Civilian?

AOA is influenced by:

- Wing configuration (flaps, slats, spoilers/speed brakes)
- Mach number
- Thrust
- Centre of Gravity



Source: Boeing Aero #12

Measurement errors

- Sensor position - not on the wing, so true AOA not known
- Local skin contours, damage
- Sensor tolerances, installation and instrument errors, contamination, bias, lag, failures

Types of AOA indicator

- Digital
- Analogue
- Indexer
- Normalised
- Haptic – tactile, physical
  - Stick shaker, stick pusher
  - Artificial buffet?
- Audio
  - Voice
  - Tone

“AOA units”

Indexer

(+ audio)

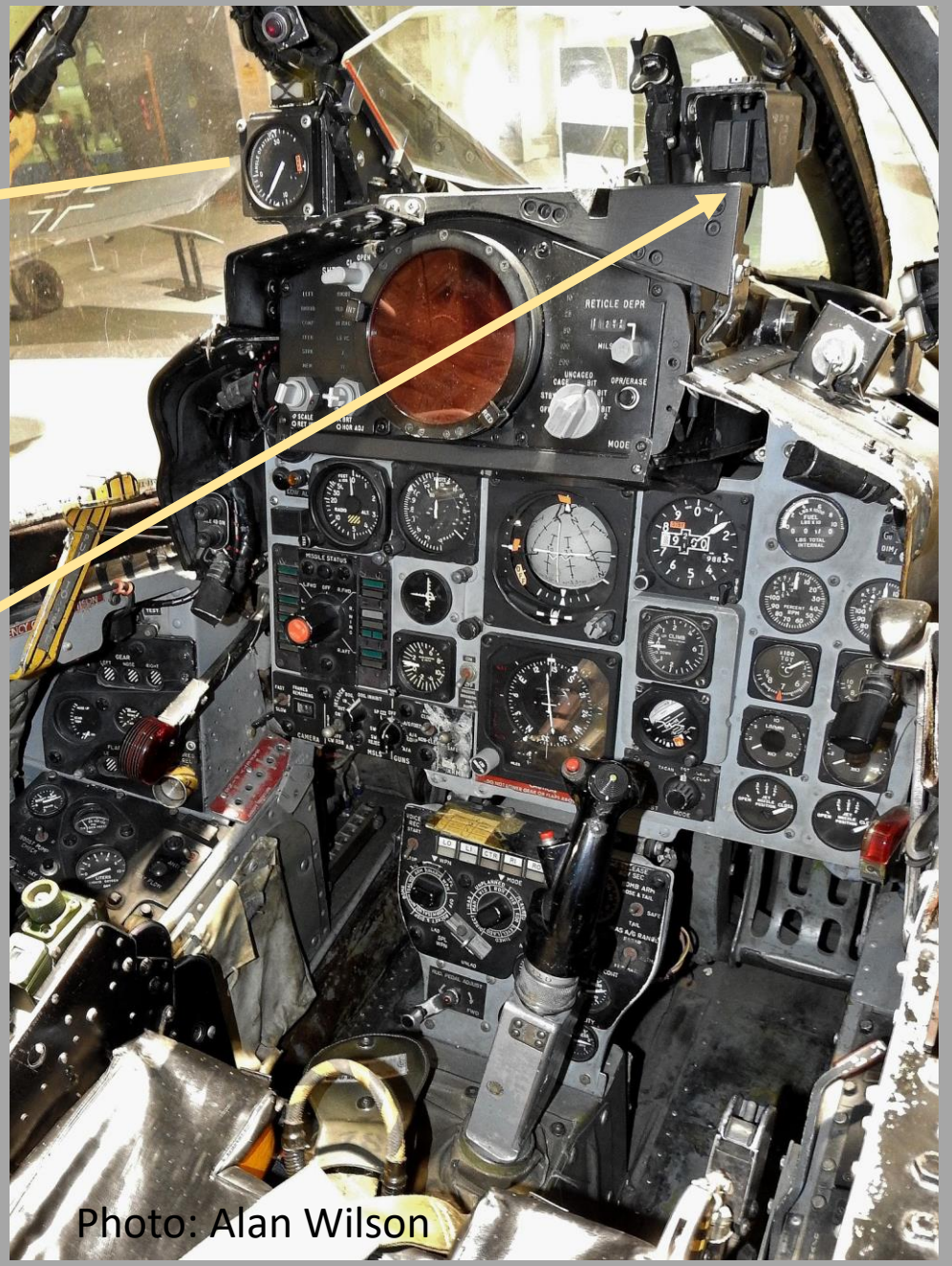
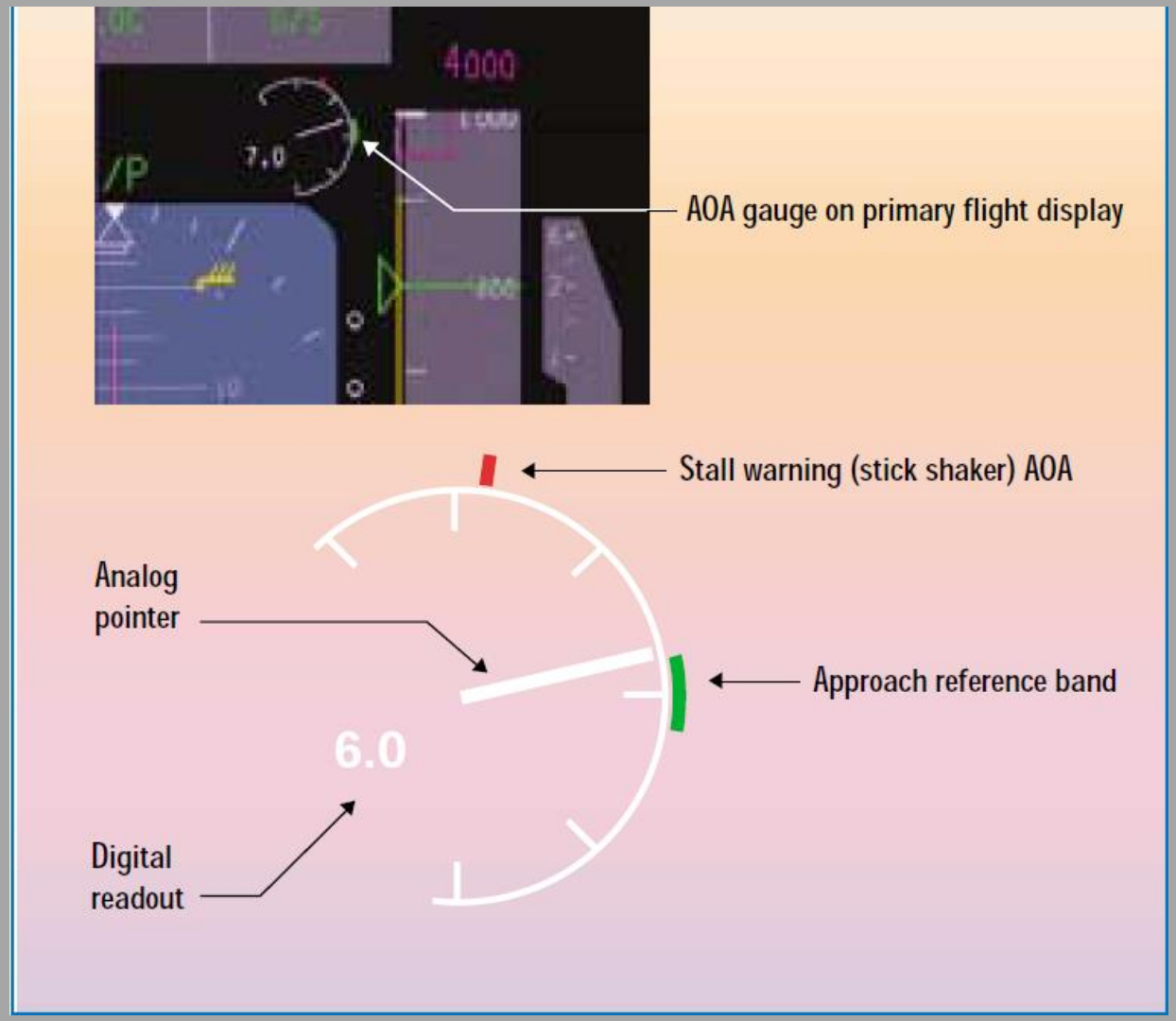


Photo: Alan Wilson


THR IDLE
DES
ALT
NAV
MDA 760
AP1
1FD2
A/THR
180
160
140
120
F
20
10
10
10
10
145
143
20
00
80
140
4000
QNH 29.92
IMED
111.10
57NM
093
12
13
14
15
16


FMC SPD
LNAV
VNAV PTH
175
427M
1400
IPOS/104°
DME ---
LNAV/VNAV
CMD
5.2
220
200
UP
1
10
10
175
10
31
32
33
160
REF
140
10
10
120
30/152
VREF
152
GS 181
3000
821M
2600
2400
29.92 IN.
30
31
32
33
34
120 H
MAG



Source: Boeing Aero #12

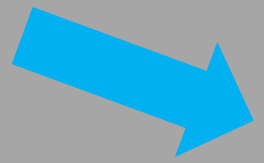
Approach band:

Weight
Min control speeds
Body angle

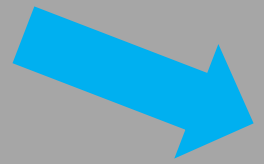
3 “R” Model

(Capt André VERNAY - DGAC)

Readiness (R1)



Recognition (R2)



Reaction (R3)

EASA CAT CAG sub-group: inappropriate flight control input

3 “R” Model

R1 - Ready

- **Fit for duty** (Is/was mentally and physically fit)
- **Trained** (Has been/was trained appropriately and is current)
- **Knowledgeable** (Has/had the knowledge relevant to the situation being faced)
- **Normal workload state** (The active workload level is/was at an optimum arousal level)
- **Engaged** (Is/was actively engaged in the task at hand)

3 “R” Model

R2- Recognise

- **Detect** The issue has first to be detected, by sensor, by scan or by other means
- **Identify** When brought to the pilots attention, it must be correctly identified
- **Understand** The issue and its implications must also be understood
- **Recall** To set in motion an action plan, it must also be recalled or if a new issue it must be treated as such

The 3 “R”s with colour coded progress through analysis

R1 – Ready from all aspects

R1 – Partially ready

R1 – Not ready

R1 – Insufficient information available

R2 – Clear and correct recognition

R2 – Partial recognition

R2 – No evidence of recognition

R2 – Insufficient information available

R3 – Correct reaction

R3 – Partially complete reaction

R3 – Incorrect reaction

R3 – Insufficient information available

Rasmussen SRK Behaviour Framework

- Skill based (SBB)
  - little or no conscious control to perform or execute an action once an intention is formed
- Rules based (RBB)
  - use of rules and procedures to select a course of action
- Knowledge based (KBB)
  - more advanced level of reasoning, used when the situation is novel or unexpected

R3- React

- **Route 1 - Conditioned Decision Making** **SBB, RBB**

- Take immediate action based on clear recognition and the recalled action plan. These form a limited number of emergencies that must be reacted to very quickly. They require a completely different approach to training than all other emergencies

RULES BASED

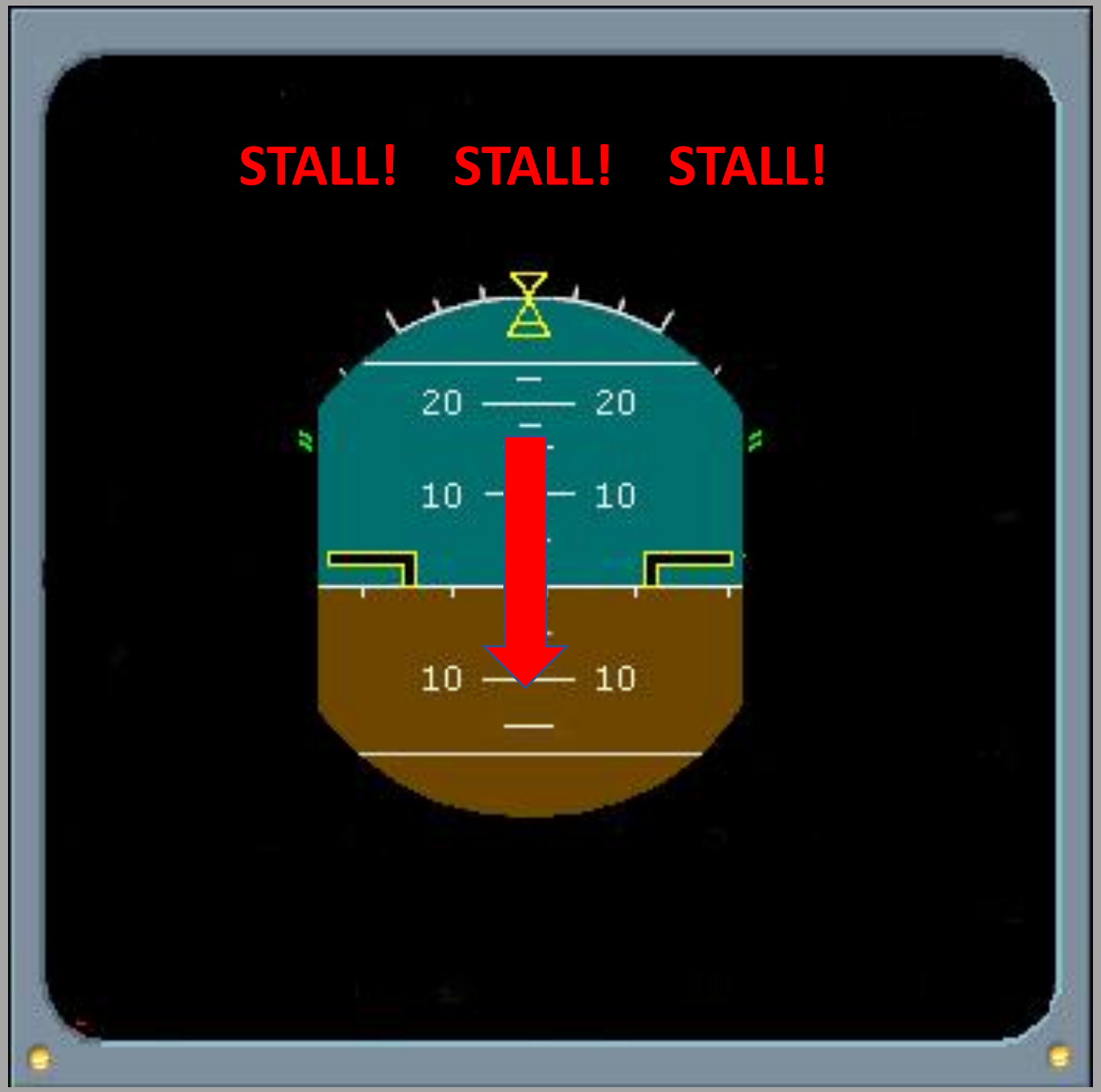
When to use indicated AOA?

- Stall…!
- Upset – valid data, therefore reasonable, calibrated AOA accuracy
- Unreliable airspeed – reduced AOA accuracy, raw data only
- Upset + UAS….?
- Landing
- Landing with UAS?

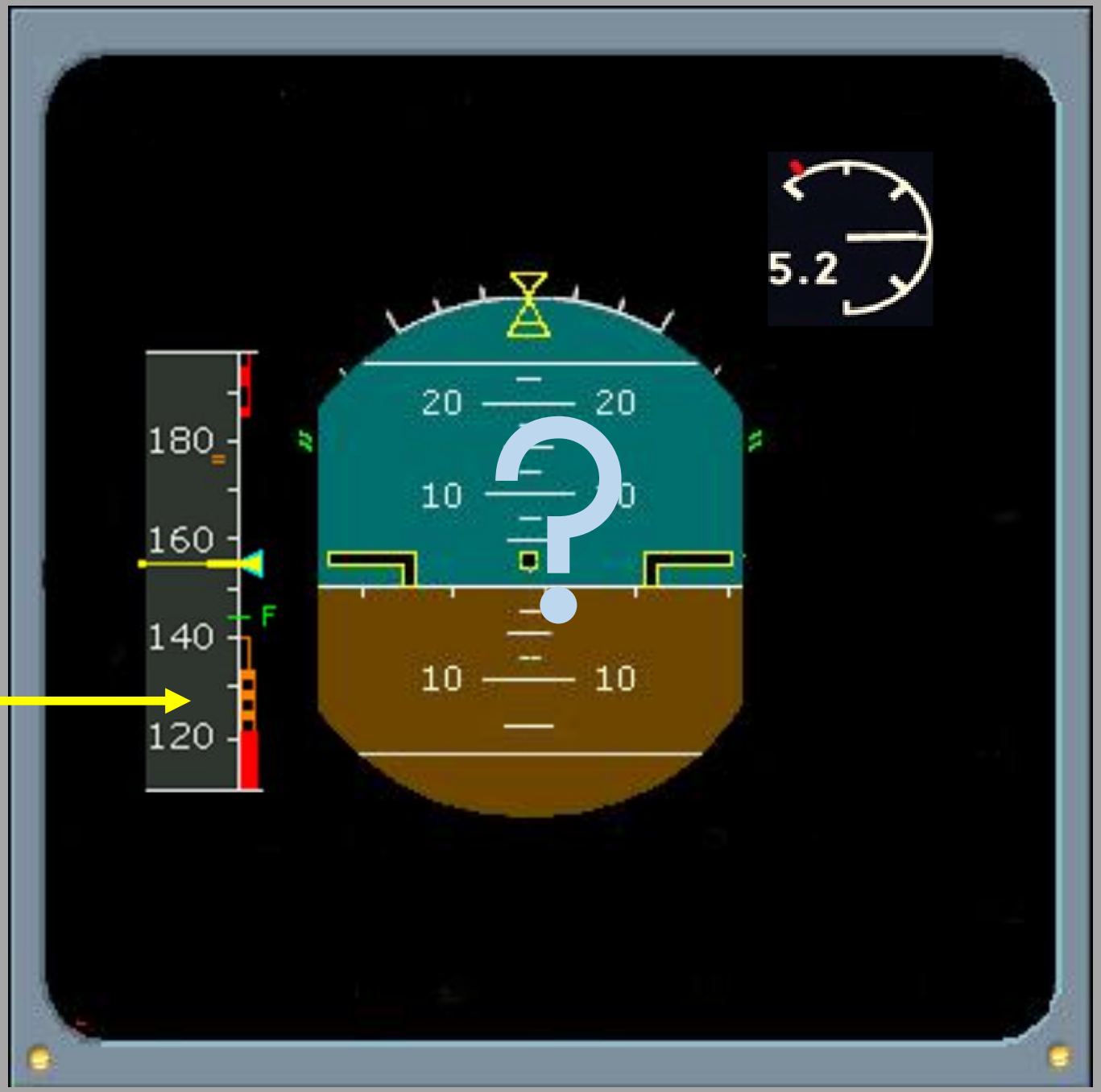
NLR STUDY – Angle of attack display in civil aircraft

(NLR-TR-2013-063)

- 15 pilots, no previous experience of AOA displays
  - Baseline PFD, AOA indicator, pitch command, fast-slow indicator
- Pitch command cue shown to be most effective at decreasing #no of stall events
- But increased secondary stalls during upset recoveries
- No difference seen between baseline PFD and separate AOA indicator
- Poor knowledge of stall factors/AOA!


STALL! STALL! STALL!
20
20
10
10
10
10

AOA ?
MARGIN
DISPLAY



Training

- Ab initio
- Simulators

A question(or a challenge):

If you agree that stalling is a once-in-a-lifetime event for CAT pilots, and that a rule-based response is therefore required, why is there such a concern about the performance of simulators in the deep stall area, i.e. outside the aerodynamic models provided by the manufacturers?

“Fidelity for the mind and not the hands…”

Training

- Ab initio
- Simulators
- Eye tracking to reinforce AOA scan
- Part-task trainers!

DIFFERENT CATEGORIES = DIFFERENT APPROACH

FLIGHT SAFETY FOUNDATION

72nd annual
INTERNATIONAL AIR SAFETY SUMMIT
IASS 2019

AOA Display - Potential FSF Actions:

(1) **Convene a group of pilot experts to determine WHEN display is appropriate**
- *Stall, upset, unreliable airspeed? Always? Never?*

(2) **Convene a group of HF, training, pilot and avionics experts to determine HOW BEST to display AOA**
- *Display stripping, haptic and auditory cues? On PFD or separate? Indexed?*

(3) **Promote research (academic and OEM) to validate and refine outputs of the WHEN and HOW BEST groups**
- *Large-scale trials, "hundreds, not handfuls"*

(4) **Training workshop to consider delivery means, career timing and rollout**
- *Simulator, part-task trainers, eye tracking, recurrent*

(5) **Develop AOA education package** – ab initio, continuous professional development

Benefits: #1-4 generate unified body of opinion and evidence for regulatory and OEM development paths
#5 for improved technical knowledge