Background

Why would you be required to use additional cognition resources in a high work load situation when a direct reading option is available and recommended?
The Boeing B737 Max accidents in Indonesia and Ethiopia were triggered by a faulty Angle of Attack(AoA) sensor which activated the MCAS. While the entire focus is on maligning the MCAS and the ethics behind concealing the documentation on it, the most critical sensor i.e. AoA is not being sufficiently investigated.

Question

Will the modified B737 Max on reintroduction to service include a direct reading AoA indicator in the cockpit and will the pilots be trained on it use is what needs to be seen? Will there be a change in the AoA sensor and redundancy?

Human cognition

The Air France Flight 447 example serves to highlight the very practical implication of the **concept of affordances** derived from the ecological view of Gibson: constraints on motor units.

This concept implies that special purpose devices or coordinative structures (Runeson 1977) can be optimally designed for the task at hand in order to minimize deviations from the targeted action that can lead to human errors. In fact, a key solution to the problem in motor control is to constrain the motor system such that degrees of freedom for the motor act match the degrees of freedom of the task (Bernstein 1967). This principle is vital when dealing with flight deck design.

Ecological representations

The goal of ecological representations is to represent task-relevant information by utilizing metaphors that reflect the control problem to leverage the experience of the interface users. The impact of this approach is that operators can learn to ‘see’ the data in the context of that deep structure, so that meaningful associations among the variables are more salient (Bennett and Flach 2011).

For complex work, this will not eliminate the need for learning and training.

However, it facilitates the types of associations that will eventually support skill-, rule- and knowledge- based solutions to complex problems (Borst, Flach, and Ellerbroek 2015).

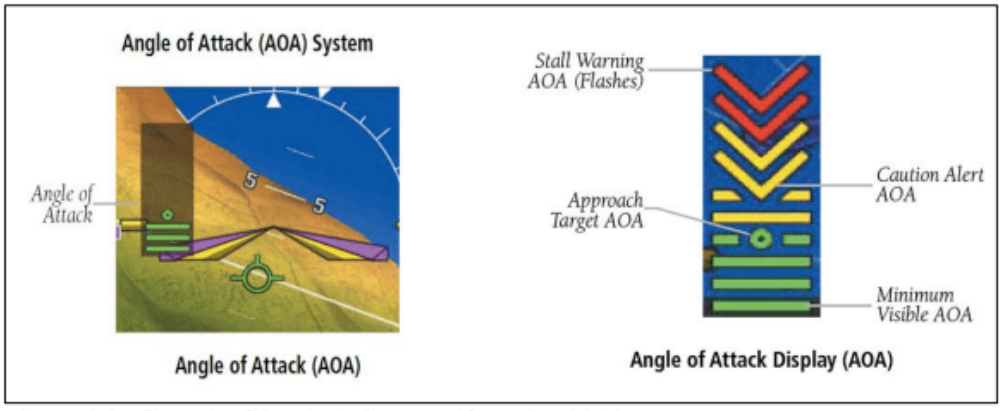
Thus, ecological

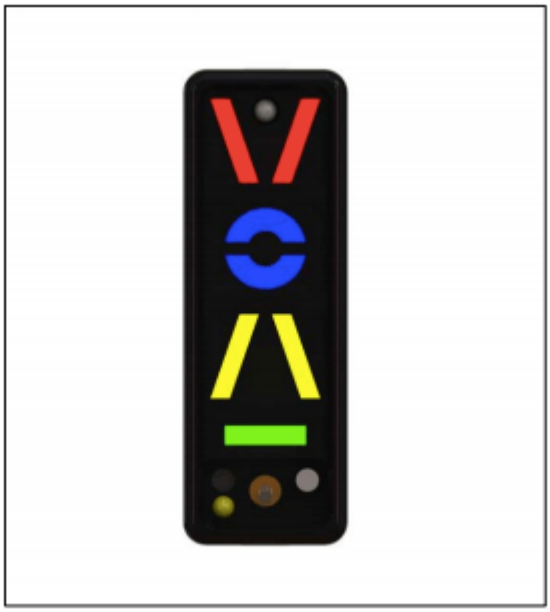
HMI should be designed to complement human expertise by representing the deep structure that experts need to think of when dealing with a given task.

Grasping the world from a cockpit: perspectives on embodied neural mechanisms underlying human performance and ergonomics in aviation context Mariateresa Sestito , John Flach and Assaf Harel

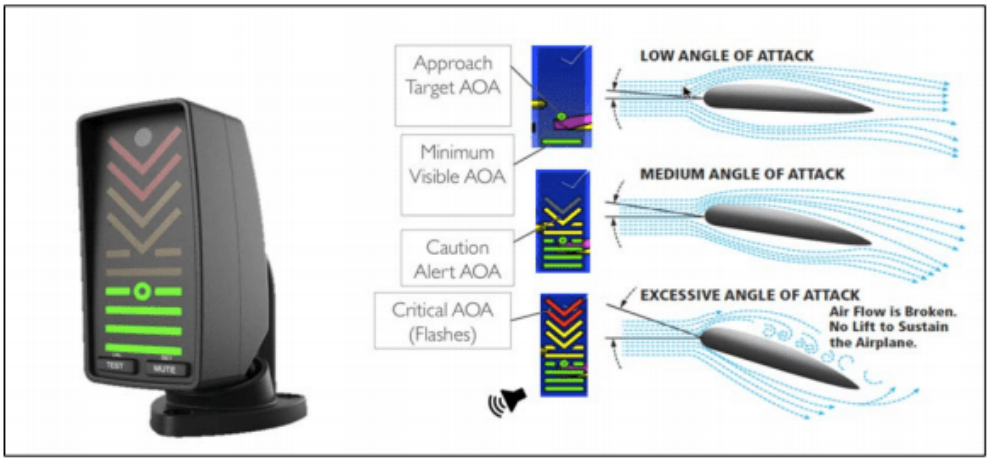
Colossal waste

Globally the aviation industry will spend over 1 billion USD on upset recovery training using Airplane Upset Prevention and Recovery Training Aid (*AUPRTA*). This is not inline with the recommendations of the AF447 accident report, NASA research on angle of attack (AOA) effectiveness, Boeing publications etc. Fighter aircrafts have been using direct reading AOA indicators since eternity. The reason for training pilots on using indirect or derived methods of recognition of AOA is simply baffling.






APPROACH
AOA



Between 2001 and 2011, aeroplane accidents resulting from a loss of control in flight (LOC-I) event were the leading cause of fatalities in commercial aviation. LOC-I accidents often have catastrophic results with very few, if any, survivors.

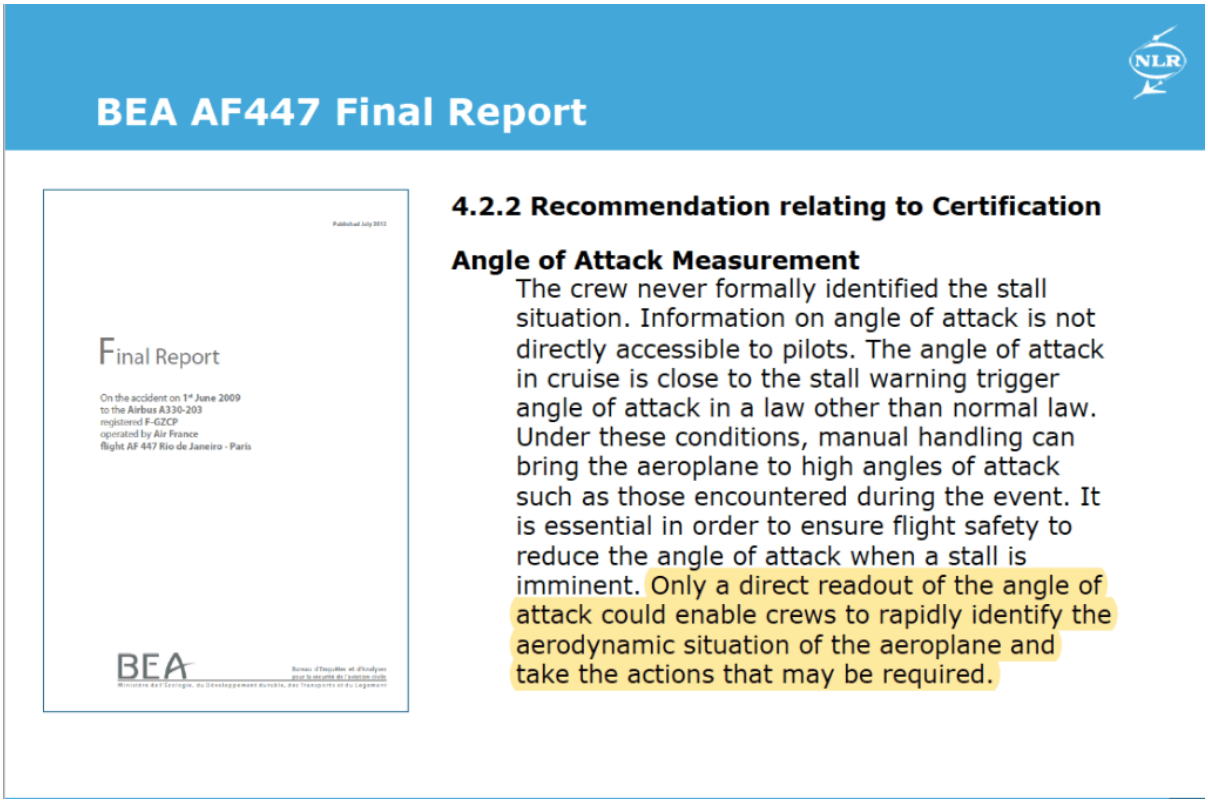
Reducing the number of LOC-I accidents is an ICAO priority, and ICAO has developed harmonized training requirements for flight crews that address and mitigate LOC-I events. Supported by ICATEE and the FAA ARC, ICAO has introduced improvements to existing Standards and Recommended

Practices (SARPs) and corresponding guidance material. Both on-aeroplane training at the commercial pilot and multi-crew pilot level and training in a flight simulation training device at the airline transport pilot and

type rating level are now promulgated in Annexes.

Image from NLR slide

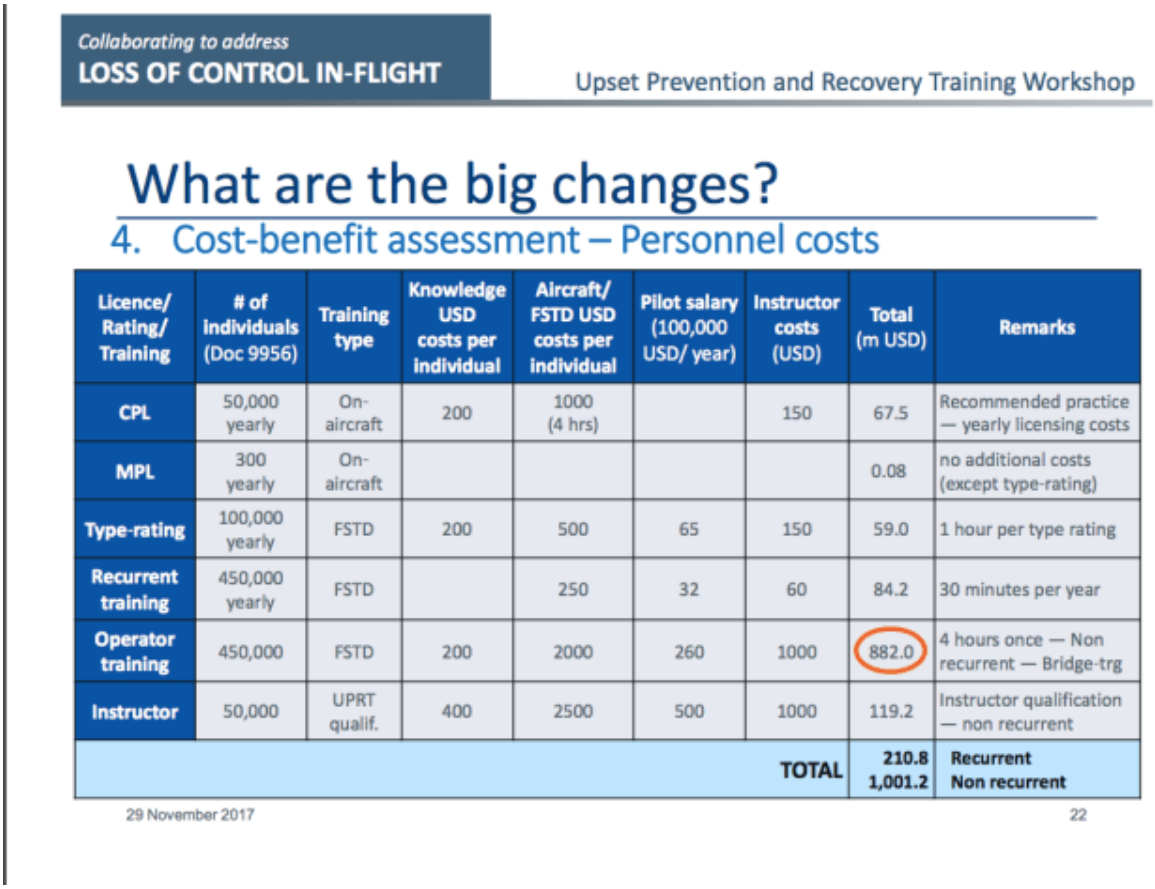
BEA Recommendation AF447



French accident investigation authority BEA

Full report

Cost



Collaborating to address
LOSS OF CONTROL IN-FLIGHT

Upset Prevention and Recovery Training Workshop

What are the big changes?

4. Cost-benefit assessment – Personnel costs

Licence/ Rating/ Training	# of individuals (Doc 9956)	Training type	Knowledge USD costs per individual	Aircraft/ FSTD USD costs per individual	Pilot salary (100,000 USD/ year)	Instructor costs (USD)	Total (m USD)	Remarks
CPL	50,000 yearly	On-aircraft	200	1000 (4 hrs)		150	67.5	Recommended practice — yearly licensing costs
MPL	300 yearly	On-aircraft					0.08	no additional costs (except type-rating)
Type-rating	100,000 yearly	FSTD	200	500	65	150	59.0	1 hour per type rating
Recurrent training	450,000 yearly	FSTD		250	32	60	84.2	30 minutes per year
Operator training	450,000	FSTD	200	2000	260	1000	882.0	4 hours once — Non recurrent — Bridge-trg
Instructor	50,000	UPRT qualif.	400	2500	500	1000	119.2	Instructor qualification — non recurrent
						TOTAL	**210.8** **1,001.2**	**Recurrent** **Non recurrent**

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UPRT training cost estimated by ICAO

NASA on Angle of Attack indicator effectiveness

AoA indicators have been shown to give pilots more accurate control and knowledge of the aircraft's performance and aerodynamics, which is especially useful as the aircraft approaches a stall. In addition, some studies have shown that AoA indicators are effective in reducing pilot workload.

Read the full report

The most beneficial use of an AoA display may be as an aid in upset prevention/recovery situations and the detection of pitot or static system failures. However, definitive works quantifying these benefits were not found. The literature did show that AoA can be a

beneficial display and may be used in the following phases of flight: take-off, climb, turning, maximizing cruise, descent, final approach, low speed maneuvers, maneuvers to flare, landing, as well as high g turns, approach to stall, and identifying and recovering from stalls at low and high altitudes.
However, definitive works that determine the requirements for an AoA display were not found.

Virtual AOA sensor

The virtual sensors are the software-based devices which use the measurable signals to reconstruct the required signal. Samara et al. designed a virtual sensor to measure the AOA based on Functional Pooling Non-linear AutoRegressive with eXogenous excitation (FP-NARX) methodology. It has been claimed that the FP-NARX methodology overcomes the limitations of the conventional virtual sensor by capturing the non-linear aircraft dynamics and capturing the aircraft behaviour under different flight conditions.

A comprehensive survey on the methods of angle of attack measurement and estimation in UAVs L. SANKARALINGAM, C. RAMPRASADH

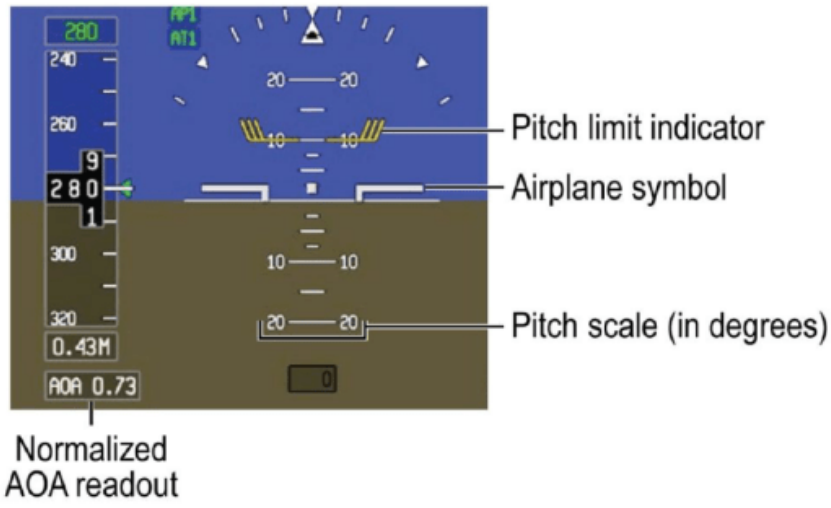
Boeing on fighters and Angle of Attack indicators

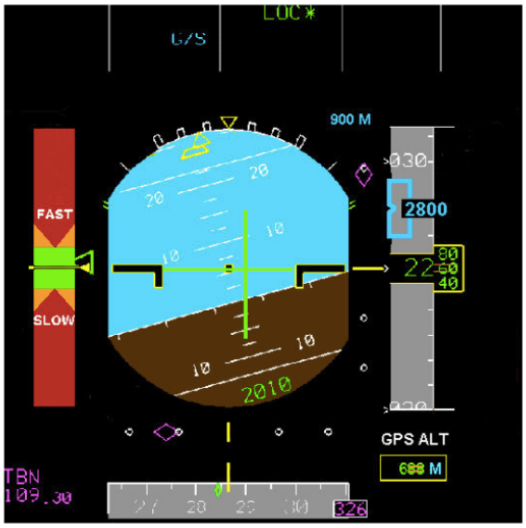
Angle of attack

AOA has been used as a primary performance parameter for years on some military aircraft, particularly on fighters. There are many good reasons for this.

In general, fighters operate more often at the extremes of the envelope, often flying at maximum lift for minimum radius turns. For other applications, AOA minimizes the pilot (usually single-place) workload by giving a simple target to fly. AOA is accurate enough for these applications. In addition, the higher sweep and lower aspect ratio of the wing reduce the sensitivity to AOA errors.AOA has proved particularly useful for approach to aircraft carriers, where it is important to maintain a consistent approach attitude for each landing. In this case, backside approach techniques are used, where glide path is controlled primarily by changes in thrust while the aircraft is held at a fixed AOA. Use of this technique during approach on commercial jet airplanes would be contrary to the pitch commands provided by the flight director bars, and to the speed hold mode of the autothrottle, which is often used during approach.

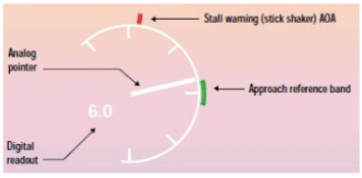
Examples of direct reading Angle of Attack indication





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.

Boeing AOA index (option on PFD)



mindFly analysis

Even for a layman the logic will be a welcome change and intriguing why has it not been made mandatory till now. A direct reading AoA indication instrument has been the main stay for the fighter aircraft which go beyond the normal envelope of flight. During a high workload situation, there is no reason that the pilots should be made to interpret and calculate the angle of attack thereby draining critical cognitive resources.

Civilian aircraft are more stable due to the nature of flying and the fact that passenger comfort is a matter of concern. There have been a series of accidents due to loss of control inflight and LOC-I is amongst the top 3 safety concerns of ICAO.

The question that arises is, if the French BEA recommended that 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, why has this not been taken into consideration?

The airlines around the world are spending in total over a billion dollar in training the

pilots on upset recovery training and preventing a stall by identifying one. Why are they relying on pitch and speed indicator through indirect methods to calculate angle of attack and take corrective actions? Manufacturers have been providing indicators, e.g Boeing 737 has an optional AOA indicator, Airbus has a BUSS which works on the principle of AOA for unreliable speed indications.

I would suggest that the airlines and other aviation safety/training bodies, review the upset recovery training process and train the pilots on the proven advantages of a simple direct reading AOA indicator in order to simplify and reduce pilot training workload. **ICAO must mandate installation of direct reading AOA indicators.**