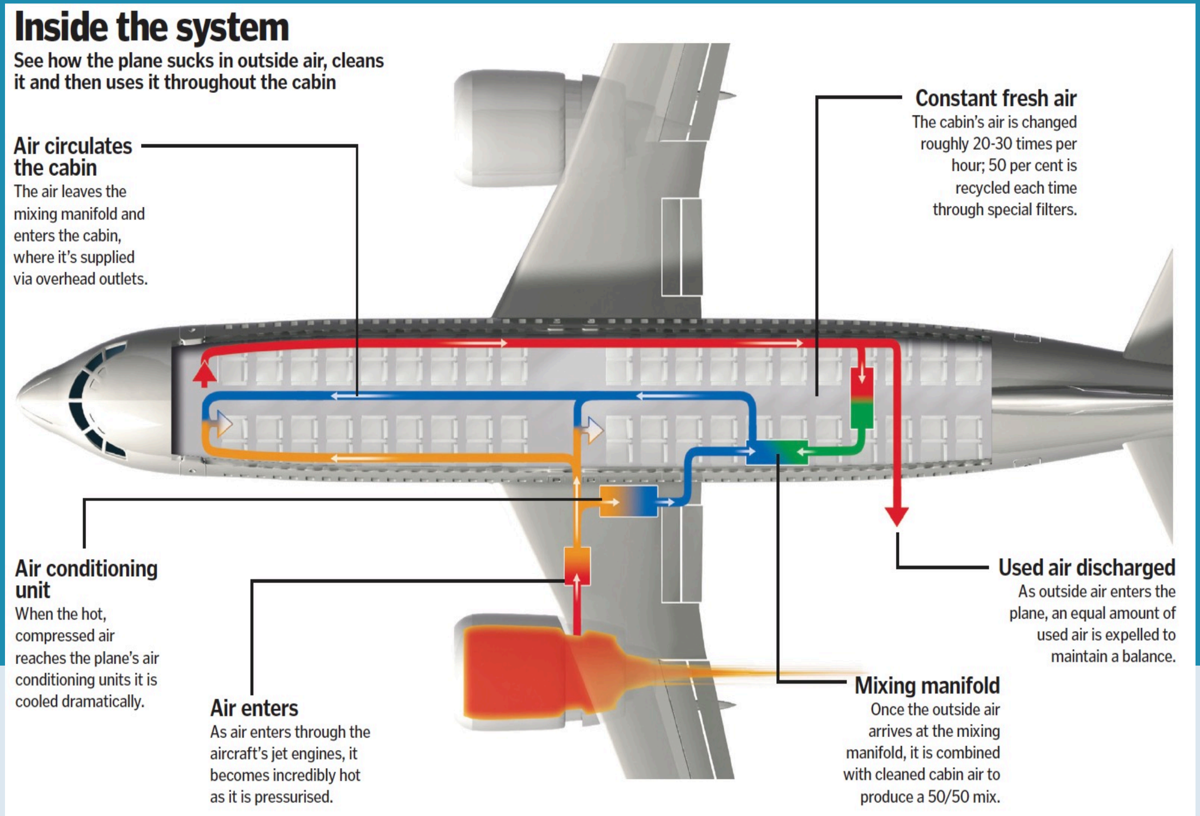
KU LEUVEN

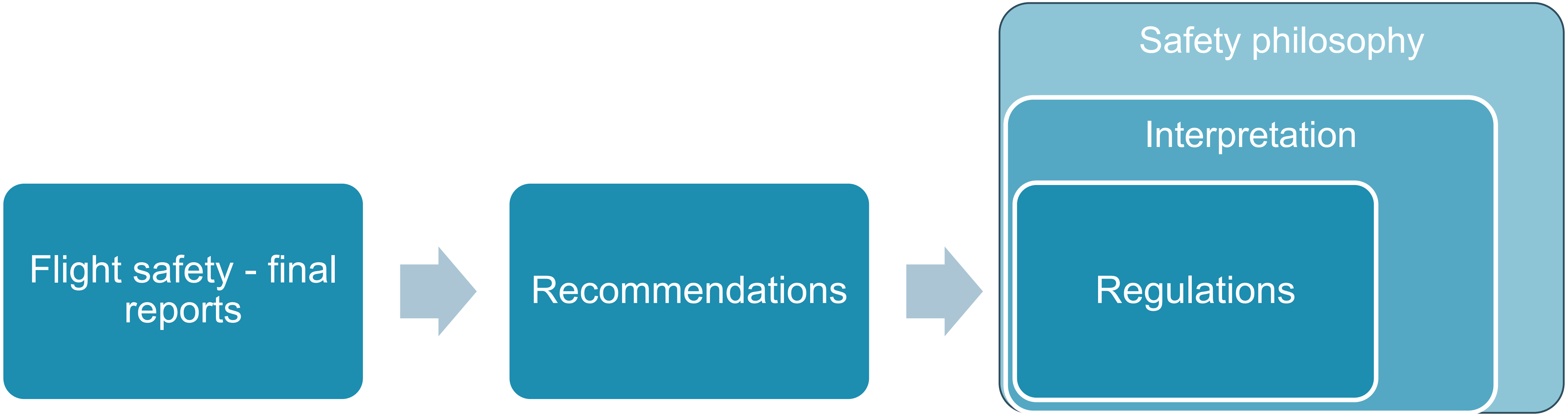
Cabin Air Contamination Sensors and European Regulations

Aircraft Cabin Air International Conference 2021



Arie Adriaensen - 15 March 2021
KU Leuven University - Dpt of Mechanical Engineering

Presentation structure



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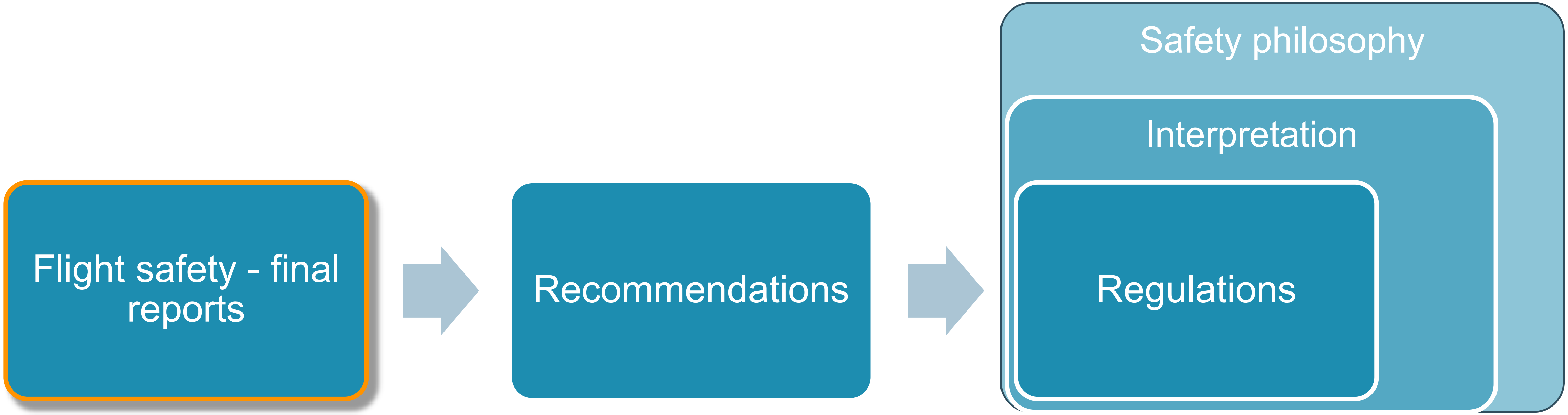
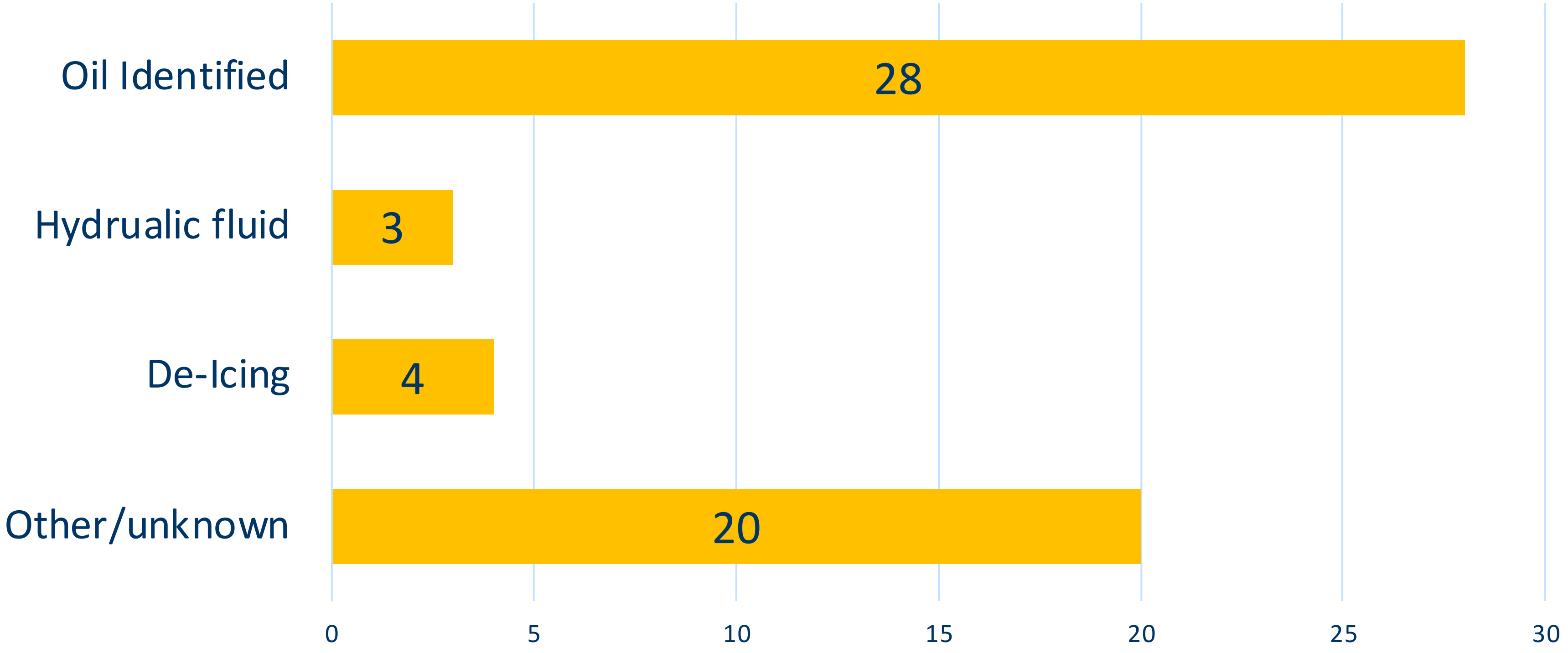


Incident Reports Root Causes 1995-2015 [1]



Incident Reports excerpts

AAIB UK

“**Smoke or fumes** in the flight deck or passenger cabin present the crew with a **potentially hazardous situation, which requires prompt action.** [3]

AAIB UK

“identified **153 reports** of smoke/fumes in addition to the investigated incident on UK fleet over a three-year period, **including 40 reports where exposure had “adverse physiological effects on one or both pilots, in some cases severe**.” [4]

SUST Switzerland

“ **Hydraulic fluids**, as they are used today in commercial aviation, fundamentally pose a **non-negligible risk potential**” [5] [translated]

EASA's interpretation of risk [9]

- "The known reported serious incidents (involving impairment or incapacitation of crews) are rare and the **safety analysis objective for such hazardous event is not put into question**"
- "The Agency is not aware of **any accident (involving injuries or loss of life or substantial aircraft damage)** for which cabin air contamination by engine or APU has been identified as the root cause."
- "Health issues are not within the primary scope of the Agency's mandate. However, the Agency would take action whenever a health case is evidenced by competent health authorities which would require a change in the design of aircraft."
- "The potential safety risk can be mitigated by existing procedures and equipment (including the use of oxygen masks)"

Presentation progress

UK final report recommendation

Safety Recommendation 2007-002 (to EASA) and 2007-003 (to FAA)

> "It is recommended that the EASA consider requiring, for all large aeroplanes operating for the purposes of commercial air transport, a system to enable the flight crew to identify rapidly the source of smoke by providing a **flight deck warning of smoke or oil mist** in the air delivered from each air conditioning unit." [4]

Austria final report recommendation

Safety Recommendation SE/SUB/LF/10/2016

> “The installation of technical **monitoring** capabilities such as **sensors** that routinely record the composition or possible contamination of the cabin air in the aircraft **in real time and warn the pilots** in due time, coupled with suitable filter systems, **should be mandatory for aircraft that use bleed air** from the engines for the cabin air.” [6] [translated]

Recommendation follow-up

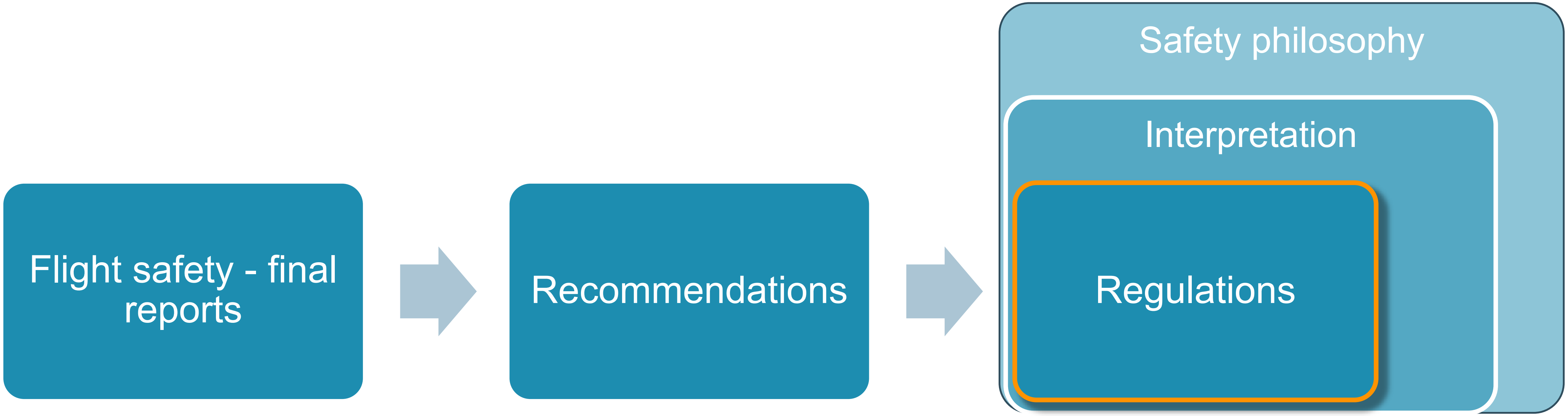
REGULATION (EC) No 216/2008:

"Results of air accident investigations should be acted upon as a matter of urgency, in particular when they relate to defective aircraft design and/or operational matters, in order to ensure consumer confidence in air transport." [7]

UK AAIB in relation to 2007-002 :

"To date, the AAIB has not received formal responses to these recommendations." [4]

Presentation progress



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EASA CS 25.1309(c) - Warning Indication

CS 25.1309(c) requires that “**information concerning unsafe system operating** conditions **must be provided to the crew to enable them to take appropriate corrective action**. Compliance with this requirement includes consideration of crew alerting cues, corrective action required, and the capability of detecting faults.” [8]

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EASA CS 25.1309(c) - Warning Indication

- “The required information will **depend on the degree of urgency** for recognition and corrective action by the crew. It should be in the form of :
- a **warning**, **if immediate recognition and corrective or compensatory action by the crew is required**;
- a **caution** if immediate crew awareness is required and subsequent crew action will be required;
- an **advisory**, if **crew awareness is required and subsequent crew action** may be required;
- a message in the other cases.” [8]

EASA CS 25.1309(c) - Warning Indication

“Some examples include reconfiguring a system, **being aware of a reduction in safety margins**, **changing the flight plan or regime, or making an unscheduled landing to reduce exposure to a more severe Failure Condition** that would result from subsequent failures or operational or environmental conditions. **Information is also required if a failure must be corrected before a subsequent flight.”** [8]

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“periodic maintenance or flight crew checks should not be used in lieu of detectors.” [8]

EASA definition unsafe condition

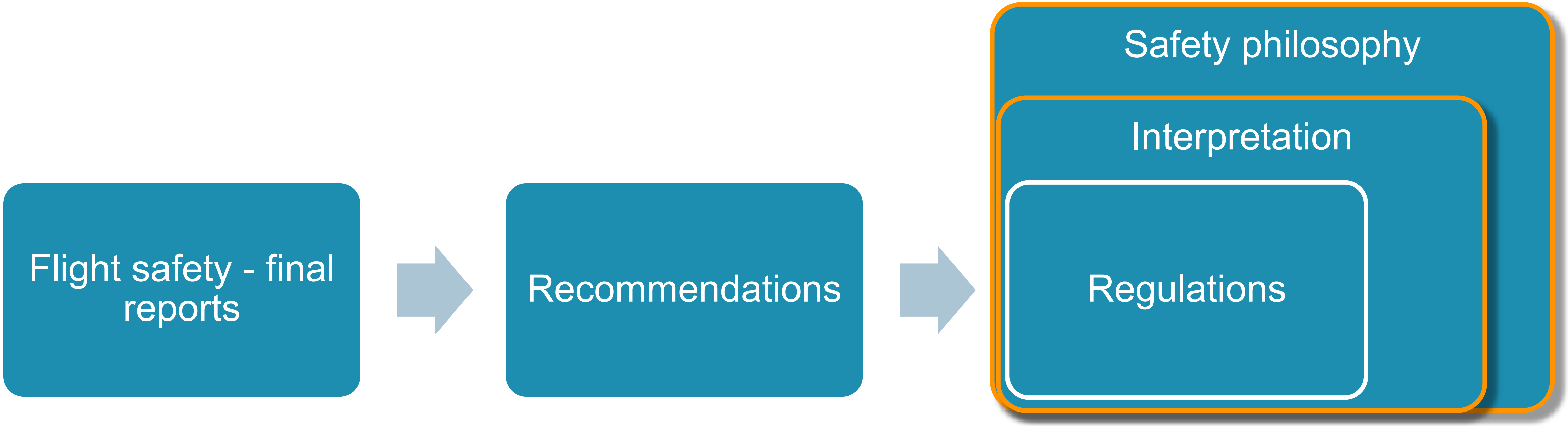
An unsafe condition exists if there is factual evidence (from service experience, analysis or tests) that:

(a) An event may occur that would result in fatalities, usually with the loss of the aircraft, or reduce the capability of the aircraft or the ability of the crew to cope with adverse operating conditions

to the extent that there would be:

- **A large reduction in safety margins or functional capabilities**
- **Physical distress or excessive workload such that the flight crew cannot be relied upon to perform their tasks accurately or completely"** [8]

Presentation structure



Failure probability versus severity [8]

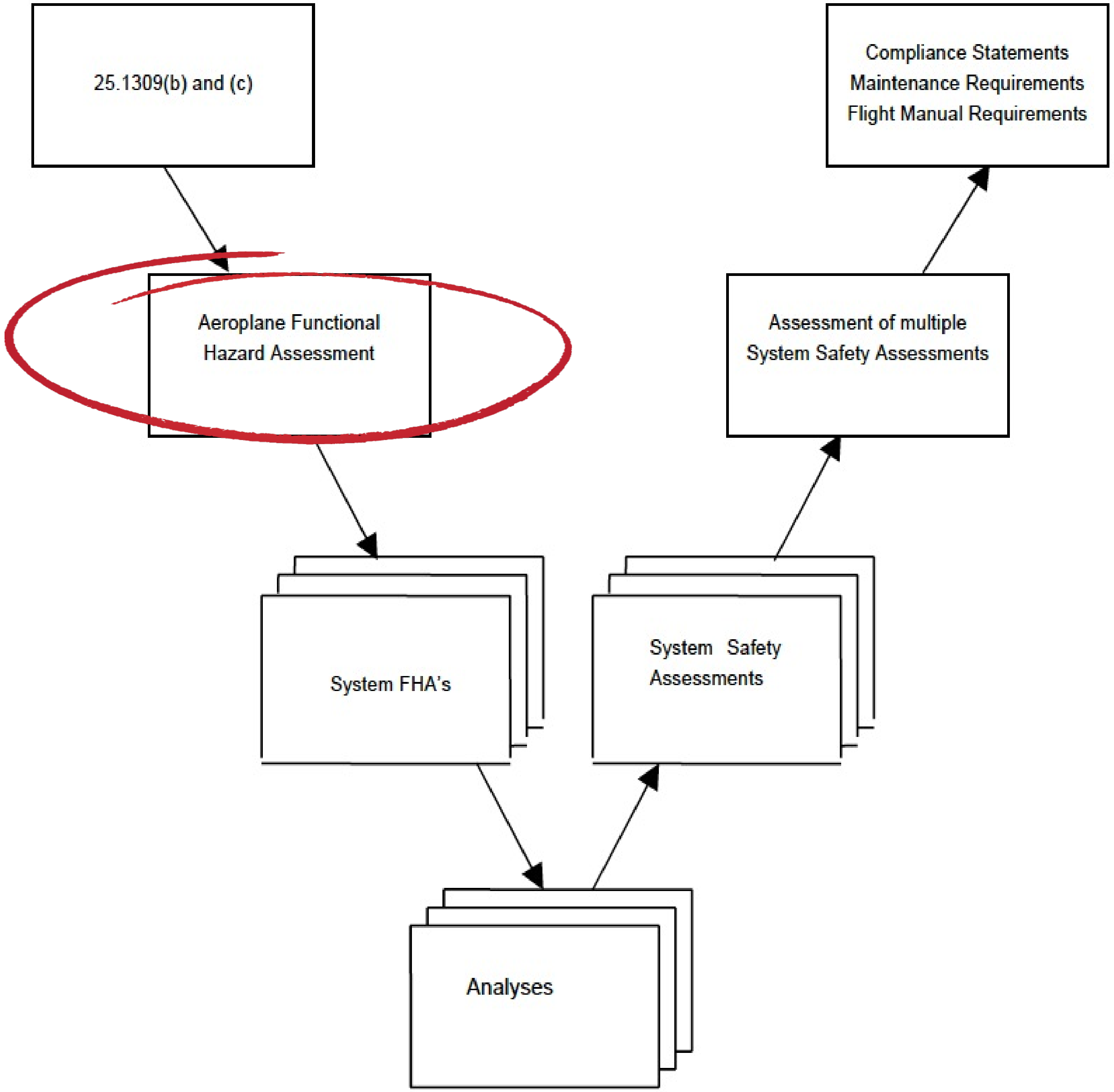
- **<u>Not</u>** for design features that have been shown to negatively affect safety. CS 25.1309(a)
- Systems should perform as intended under all foreseeable operating conditions and **should not pose a danger in themselves.** CS 25.1309(a)
- Effects of failure probability, not accident probability

Effect on Aeroplane	No effect on operational capabilities or safety	Slight reduction in functional capabilities or safety margins	Significant reduction in functional capabilities or safety margins	Large reduction in functional capabilities or safety margins	Normally with hull loss
Effect on Occupants excluding Flight Crew	Inconvenience	Physical discomfort	Physical distress, possibly including injuries	Serious or fatal injury to a small number of passengers or cabin crew	Multiple fatalities
Effect on Flight Crew	No effect on flight crew	Slight increase in workload	Physical discomfort or a significant increase in workload	Physical distress or excessive workload impairs ability to perform tasks	Fatalities or incapacitation
Allowable Qualitative Probability	No Probability Requirement	<---Probable---->	<-----Remote---->	Extremely <------------------> Remote	Extremely Improbable
Allowable Quantitative Probability: Average Probability per Flight Hour on the Order of:	No Probability Requirement	<------------------> $<10^{-3}$ Note 1	<------------------> $<10^{-5}$	<------------------> $<10^{-7}$	$<10^{-9}$
Classification of Failure Conditions	No Safety Effect	<-----Minor------>	<-----Major------>	<--Hazardous-->	Catastrophic

Note 1: A numerical probability range is provided here as a reference. The applicant is not required to perform a quantitative analysis, nor substantiate by such an analysis, that this numerical criteria has been met for Minor Failure Conditions. Current transport category aeroplane products are regarded as meeting this standard simply by using current commonly-accepted industry practice.

Functional Hazard Assessment

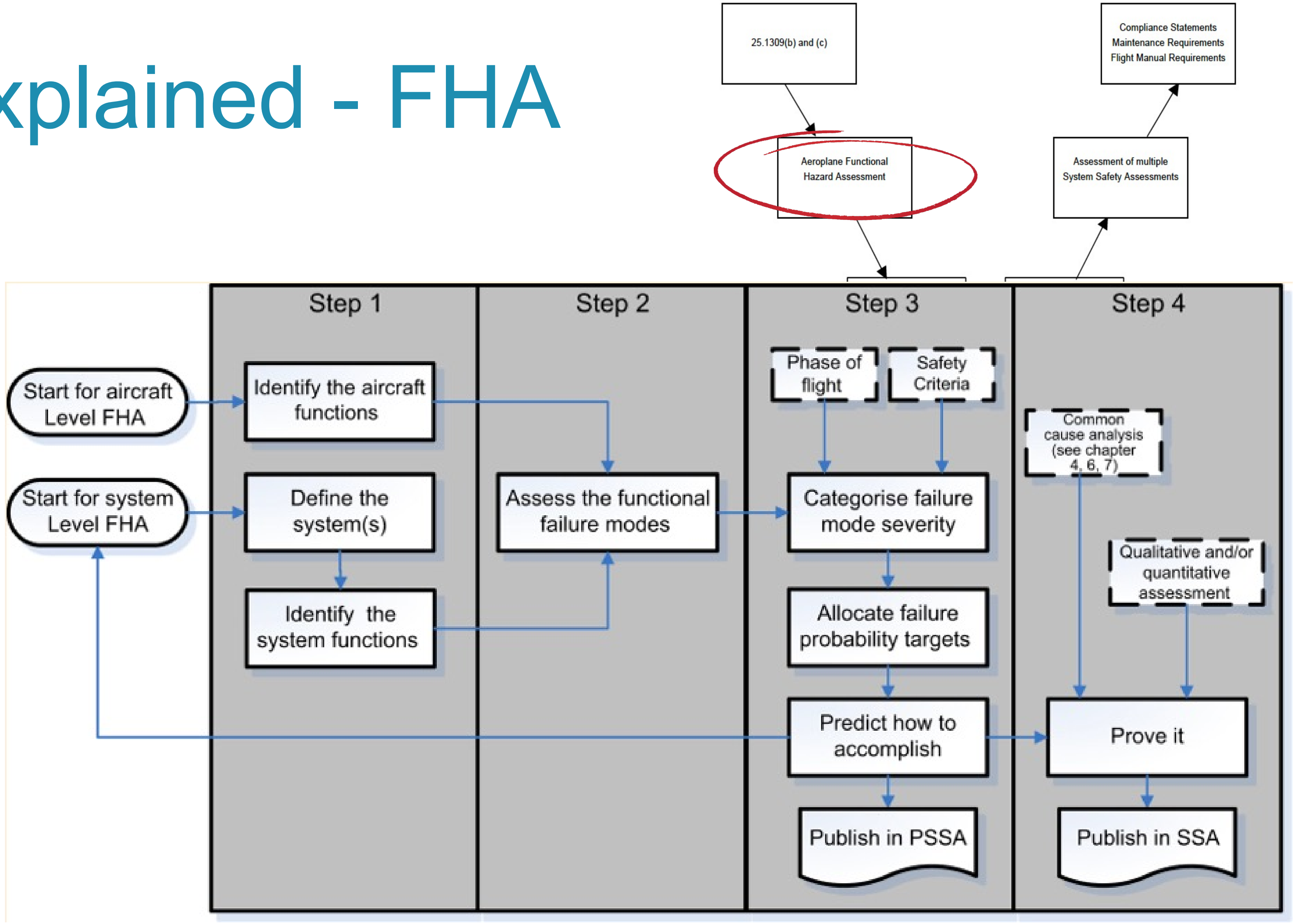
Safety targets without system architecture



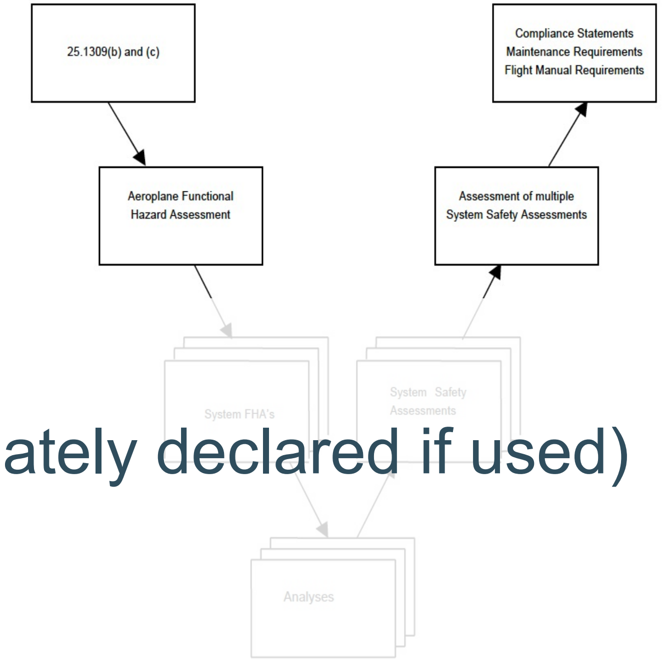
Aviation safety explained - FHA

Aim <u>preliminary functional</u> hazard assessment [10]

- safety objectives of the system relative to the identified functional failure modes
- **not consider the system architecture**
- consider the **worst case effects**



FHA philosophy



"The following factors should be considered (and appropriately declared if used) when determining the severity of a failure condition:

- **time to detection** (i.e. when detected);
- failure recognition provided (i.e. how detected)
- how would the pilot react (i.e. what to do) to cope with the failure and the timeliness thereof" [10]

EASA's interpretation of risk [9]

- "The known reported serious incidents (involving impairment or incapacitation of crews) are rare and the safety analysis objective for such hazardous event is not put into question"
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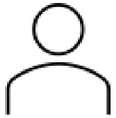
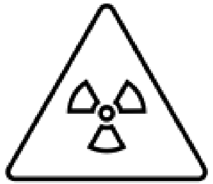
Risk in safety engineering

RISK = probability x severity x detection

Risk in safety engineering

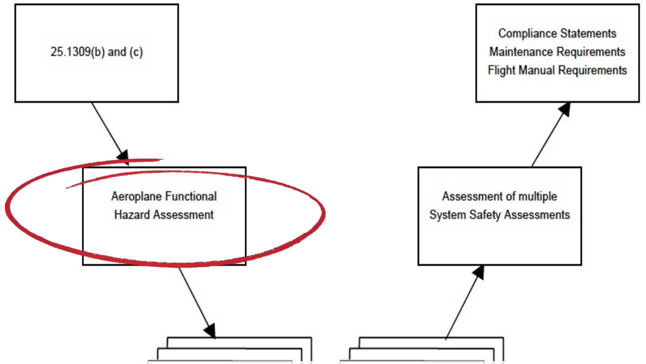




RISK = probability x severity x detection

Crew = detection & system operator

FHA philosophy



- “When assessing the consequences of a given failure condition, account should be taken of the warnings given, the complexity of the crew action. [10]
- Pilots and cabin crews should form an integral part of such discussions as many Safety Assessors have little to no operational experience.” [10]
- “Extensive service experience alone showing that the failure condition has not yet occurred is not sufficient reason to indicate that a single failure condition cannot exist.” [10]

References used

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Contact:
arie.adriaensen@kuleuven.be