Cabin Air Quality

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- Research and technology
- Sensors
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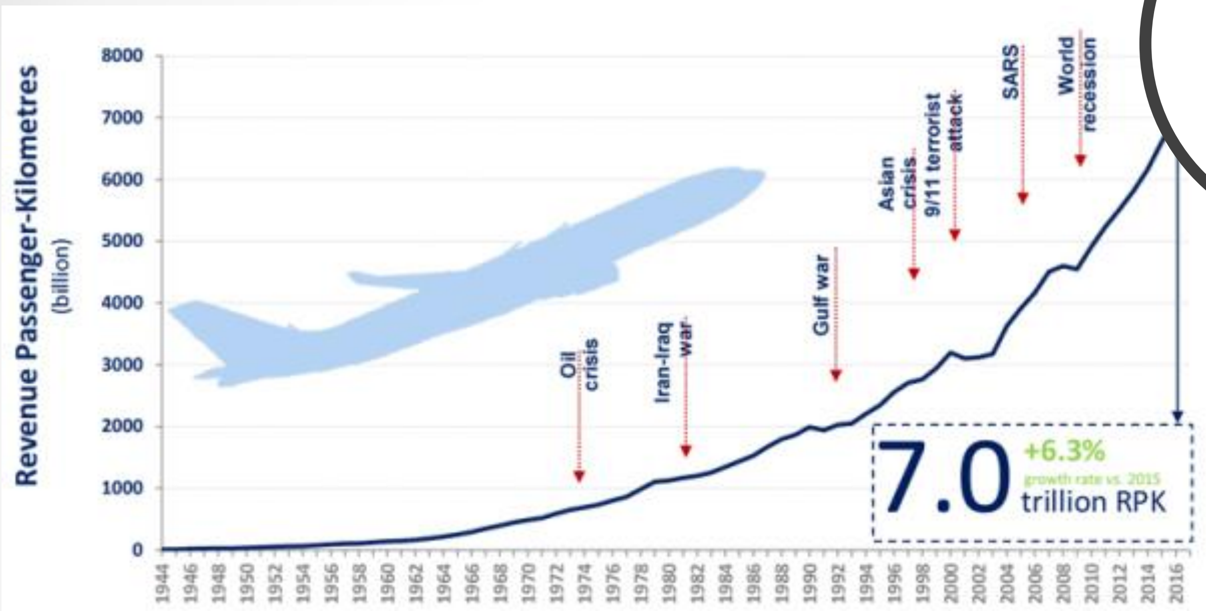
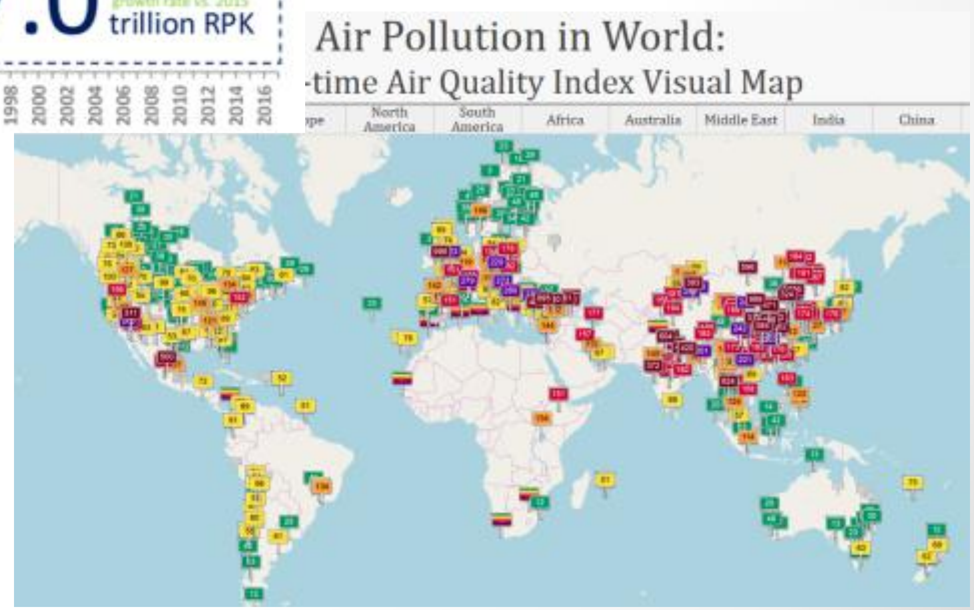
Overall context



2xPAX/ 15years



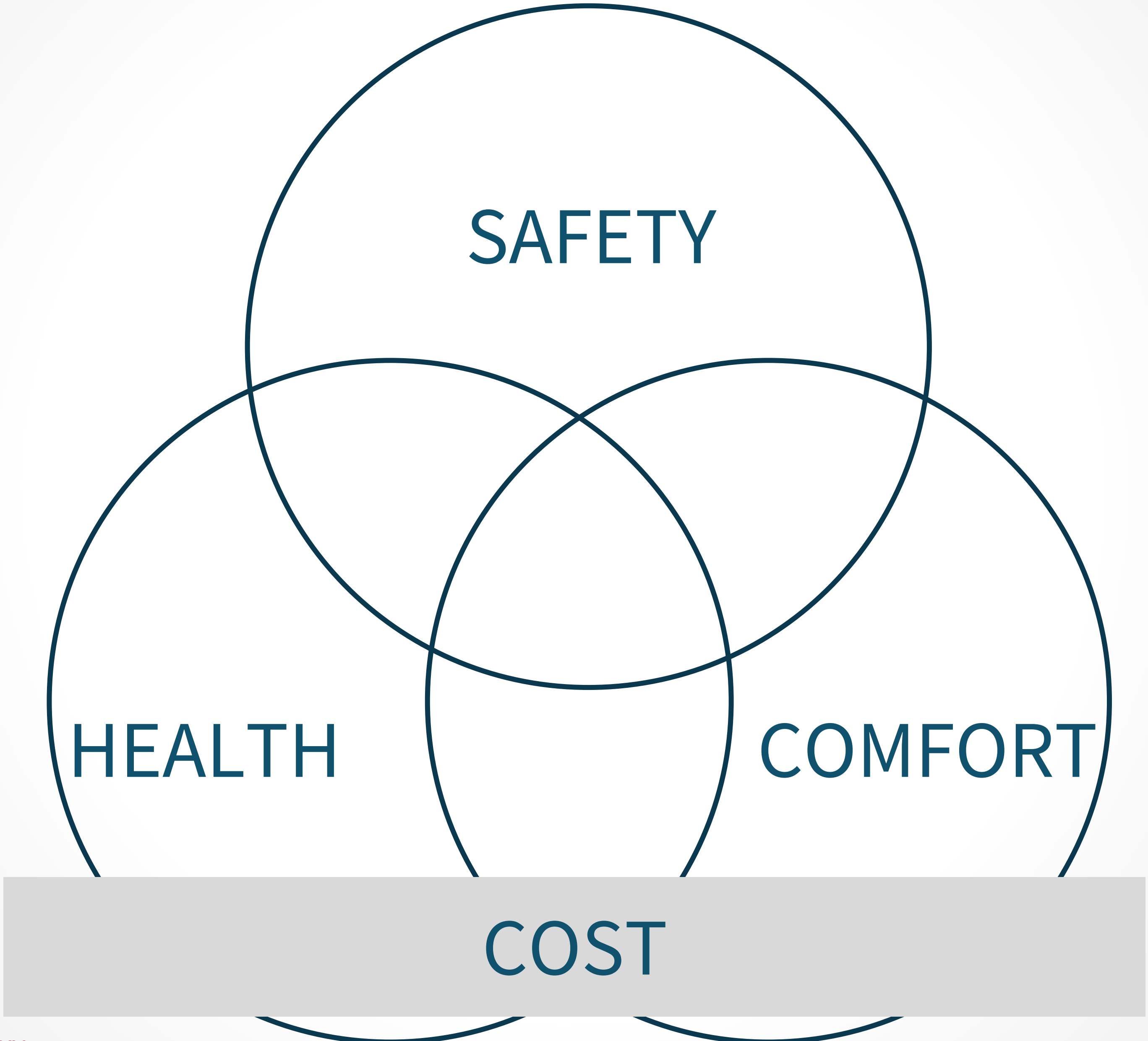
Global Warming
Increased air quality awareness
Democratization of
monitoring and reporting

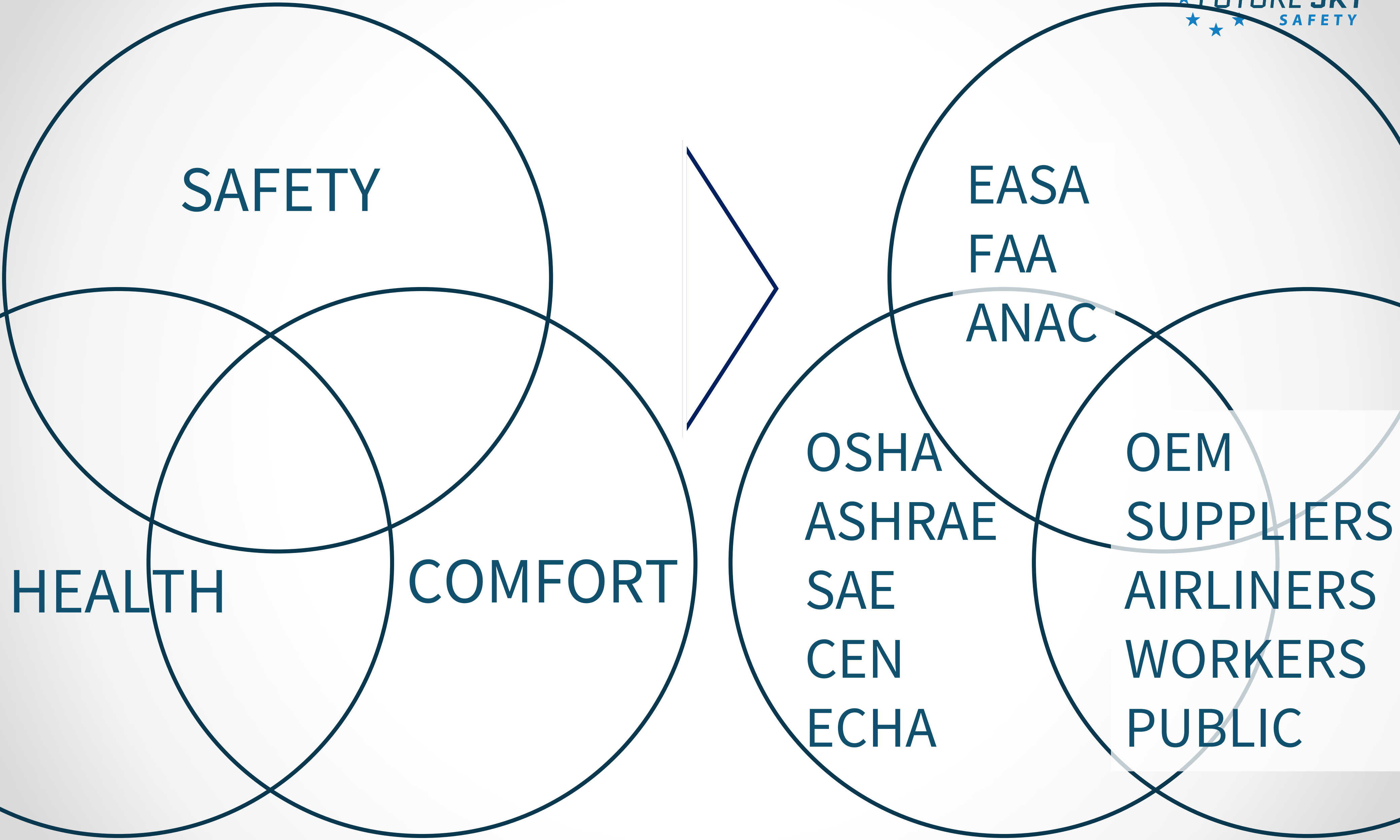
CABIN

Commercial Aircraft
Executive jets
... On Demand Mobility?

Credit: newFACE: http://newface.inegi.up.pt
Almadesign, SETsa, INEGI, Embraer
COMPETE, QREN (FEDER)

CAQ




SAFETY
HEALTH
COMFORT
EASA
FAA
ANAC
OSHA
ASHRAE
SAE
CEN
ECHA
OEM
SUPPLIERS
AIRLINERS
WORKERS
PUBLIC

Working definition (FSS 7.3)

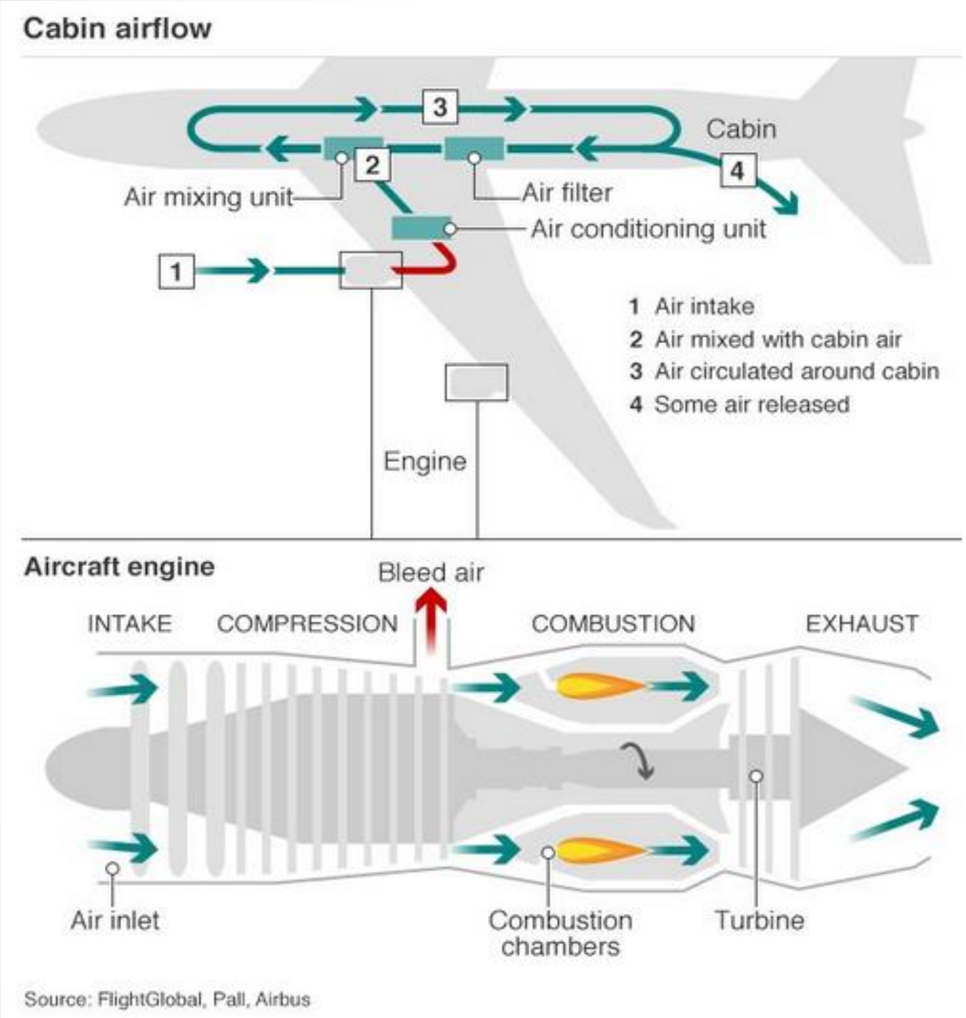
“Cabin air quality is the holistic (physical, chemical, biological, radiological) characteristics of cabin air.

A/C cabin: a challenging environment

The cabin is an enclosed, complex environment, with high density of occupants and furnishings.

- **On ground:** airport environment (fuel, particles, pollution), de-icing fluids
- **In flight:** systems malfunction (eg, engine oil from bad sealing), outside air (eg, Ozone@high altitude)
- **From within:** people (CO_2, VOC/SVOC, odours), cleaning substances, furnishings and equipment (eg, galley, WC, ECS,…)

CAQ: managing the A/C environment (I)



OUTSIDE

~[-60 : 50] ºC

~[10 : 100] kPa

[0 : 100] %Relative Humidity

Ozone, etc…

INSIDE

22±2 ºC

~[75:100] kPa

~[10:20] %Relative Humidity

CAQ: managing the A/C environment (II)

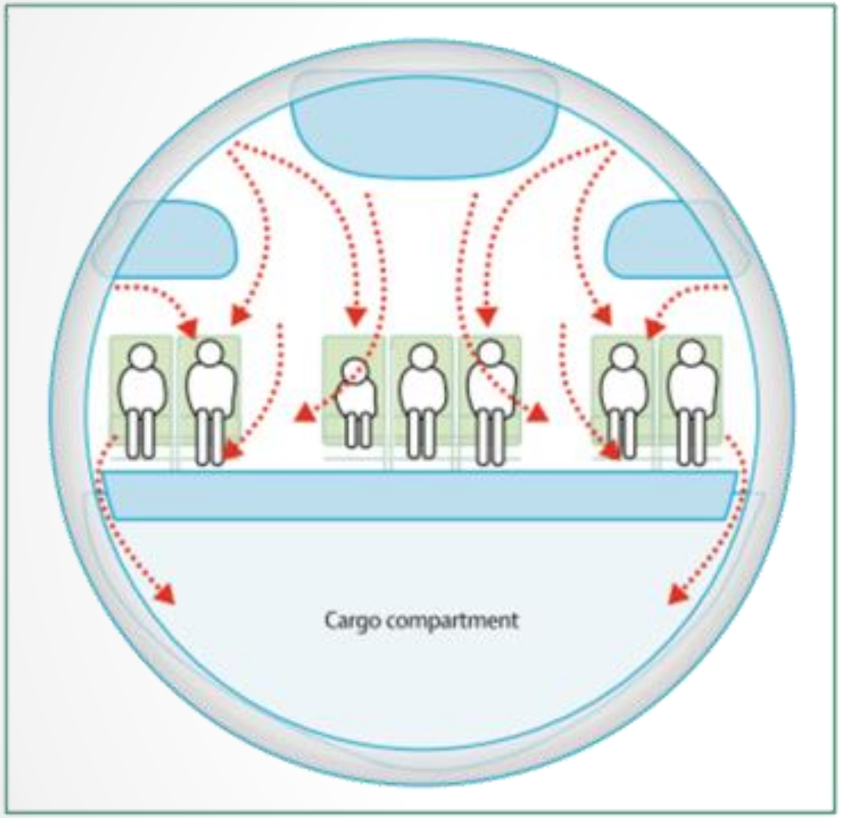


Figure 1: Air circulation pattern in typical airline passenger cabin

Air Circulation

50% recirculation of air

recirculation by cross-sections

1 renewal every 2,3 min.

HEPA filters

Ozone catalizers

Sources: "Transmission of infectious diseases during commercial air travel ",Alexandra Mangili, Mark A Gendreau, 2005
"On the 2-Row Rule for Infectious Disease Transmission on Aircraft," V. S. Hertzberg and H. Weiss, 2016

CAQ: A/C vs buildings

Table 3
Selected environmental and occupational conditions in aircraft cabins and in offices, and exposure impact.

Condition	Aircraft cabin	Offices	Exposure impact
Contamination	Bleed air: tricresyl phosphates, deicing fluids, disinfectants, flame retardants, and plasticizers	Cleaning chemicals, material emissions, traffic pollutants, flame retardants, and plasticizers	Episodic events of temporary elevated exposure Possible thermal degradation Possible ozonolysis
Ozone, µg/m^3	High concentrations may occur (100–200 µg/m^3).	Certain regions have high outdoor concentrations, I/O ratios typically 0.2–0.7. Use of air cleaning devices and photocopiers may add substantially to the background level.	Higher concentrations initiate more gas- and surface reactions with unsaturated VOCs producing gas-phase and secondary organic aerosols (ultrafines). Dirty ventilation systems may emit ozone-initiated reaction products, e.g., 4-OPA.
Non-reactive VOCs	Variety of compounds		Likely to be similar patterns
Reactive VOCs (unsaturated)	High concentration of limonene from drink and meal services	High temporary concentration from use of consumer products, e.g., cleaning agents and orange peel; air fresheners may be constant sources.	Temporary high concentrations of oxygenated species may occur including, formaldehyde, 4-AMCH, IPOH, 6-MHO and 4-OPA, and other species can occur.
Reactive surfaces	Large surface area: high density of passengers, clothing, and textiles (seats and textile flooring)	Moderate surface area: moderate density of workers and textile flooring	The larger and the more soiled the surface the more ozone-initiated production of oxygenated species by surface reactions, e.g., 4-OPA.
Relative humidity (RH), %	<10	30–50	The lower the RH the more aqueous loss and decrease of tear production and PTF stability. Less stable PTF may become more susceptible to sensory irritants.
Temperature (T), °C	20–25	20–25	High T decreases tear production from the lacrimal gland, thus altering PFT stability.
Altitude, reduced pressure	Yes	No	Reduced pressure or high altitude enhances aqueous loss from the ocular surface and skin resulting in altered PTF.
Visual display unit (VDU) work Instrumental surveillance	Pilots	Yes, several hours.	VDU or surveillance work alters the PTF stability by a decrease of the eye blink frequency.
Combustion products, e.g., traffic	No	Infiltrated outdoor air, NO_2, particles	Combustion products may alter the PTF.

Peder Wolkoff, Derrick R. Crump, Paul T.C. Harrison,
Pollutant exposures and health symptoms in aircrew and office workers: Is there a link?,

Safety/Health : fumes and odours

EASA Study (2017)

- Preliminary results:
  - From flight measurements (limited) : CAQ similar or better than other indoor environments ;
  - Causal link between fumes events and health: addressed in FACTS
- New large scale study: FACTS
- Focus on abnormal events, innovative methodology by simulating fume events.

REACH

- NL requested TCP evaluation (2012)
- Information submission deadline (2018)
  - Neurotoxity
  - Exposure
  - Information questionnaires, medical and clinical investigations
- Evaluation (2019)

Safety/Health : fumes and odours

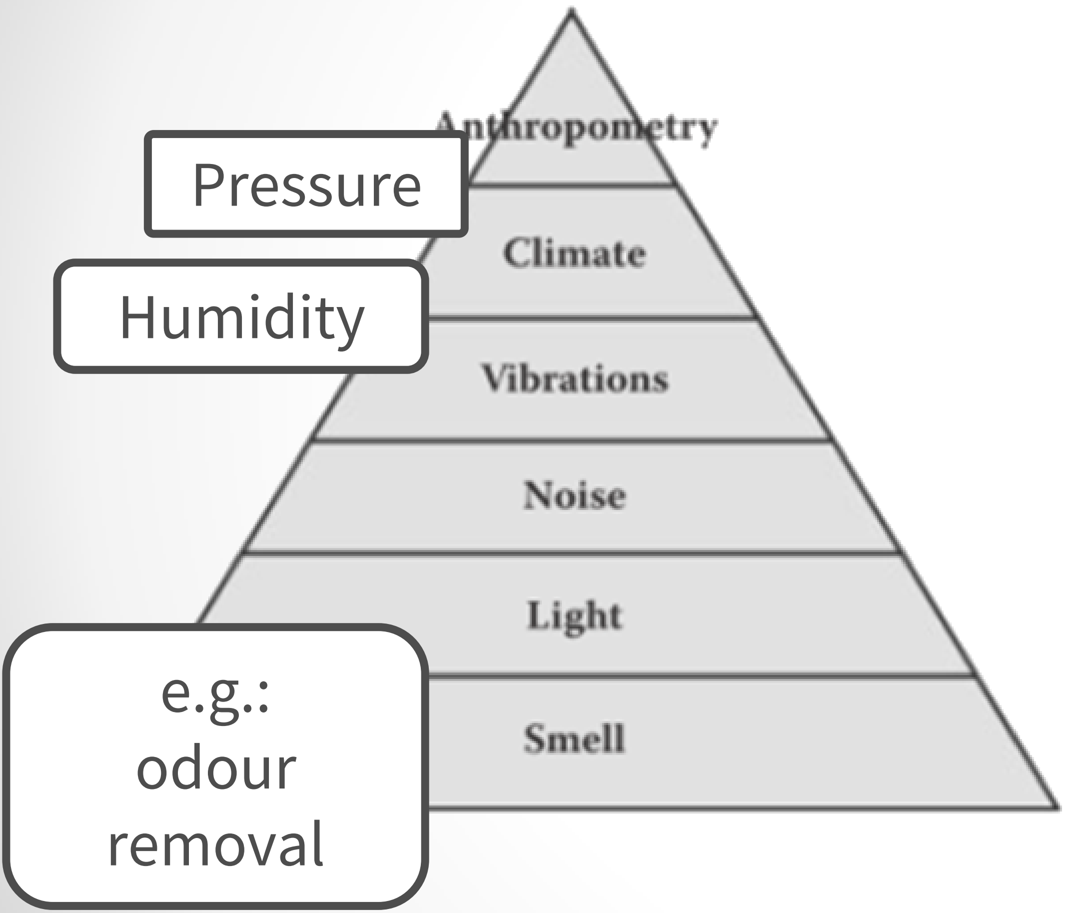
SAE

- Cabin Air Quality Measurement Committee
- 2017, after IATA request Nov 2016
- “(..) standards for the measurement of air quality within the cockpit and passenger compartments. (..) developing a standard or standards covering portable and/or fixed installation sensors to quantitatively measure fumes and contaminants that could enter the cabin space.”

CEN/TC 436

- Cabin Air Quality on civil aircraft – chemical agents
- develop European standards on "Cabin air quality on civil aircraft - Chemical agents" suitable for all stakeholders including passenger organizations , crew associations, aircraft and engine manufacturers, parts and components manufacturers, airlines and OSH (Occupational Safety and Health) representatives.

OPPORTUNITIES



- Composites (higher humidity and cabin pressure)
- Improving systems (more electric aircraft, control systems, …)
- Emergence new low cost, weight and energy sensors
- Improved comfort leads to higher productivity

Picutre source: "Aircraft Interior Comfort and Design", Peter Vink and Klaus Brauer 2011

On board sensors / continuous sensing

Table 2. Cabin environmental quality issues relevant to stakeholders.

Stakeholder	Sensor-Related Issues
Regulatory agencies	Compliance with FARS and ASHRAE Standard
Aircraft manufacturers	Safety, low cost, simplicity, maintenance alerts, aircraft ECS design improvements. 'level playing field'
Airlines[a]	Revenue, passenger comfort, minimal complaints, 'level playing field'
Crew	Documenting exposures to contaminants (hydraulic fluids, pyrolysis products, pesticides); health risks; chemical sensitivity; compliance with standards; discomfort; access to data
Passengers	Health risks, comfort, access to data
Researchers	Exposure data related to health research and aircraft design improvements; access to data

Source: "Aircraft Cabin EnvironmentalQuality Sensors", 2010

FUTURE SKY SAFETY

On-board sensing: different approaches

Human Reporting

Industry Sensor Network


OACI

Cir 344-AN/202

Orientations sur les pratiques éducatives, de formation et de compte rendu concernant les émanations

ORGANISATION DE L'AVIATION CIVILE INTERNATIONALE

On-board sensing: human reports

Human nose is an excellent "sensor";
Readly available;
Standardized Procedure;

Humans prone to subjectivity, consistency and reliability issues.

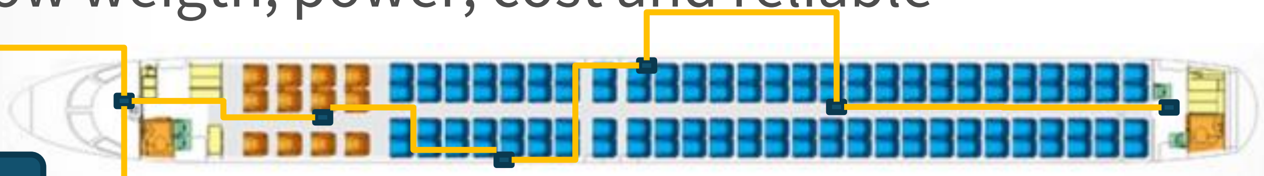
ICFAS: Industrial cabin air quality Framework based on Continuous Air quality Sensing

Requirements:

- Interface with aircraft (future/legacy)
- Physical interfaces for sensors and operation
- Functions through interface
- Low weigth, power, cost and reliable

Astrium E-Nose
DLR projet

JPL e-nose



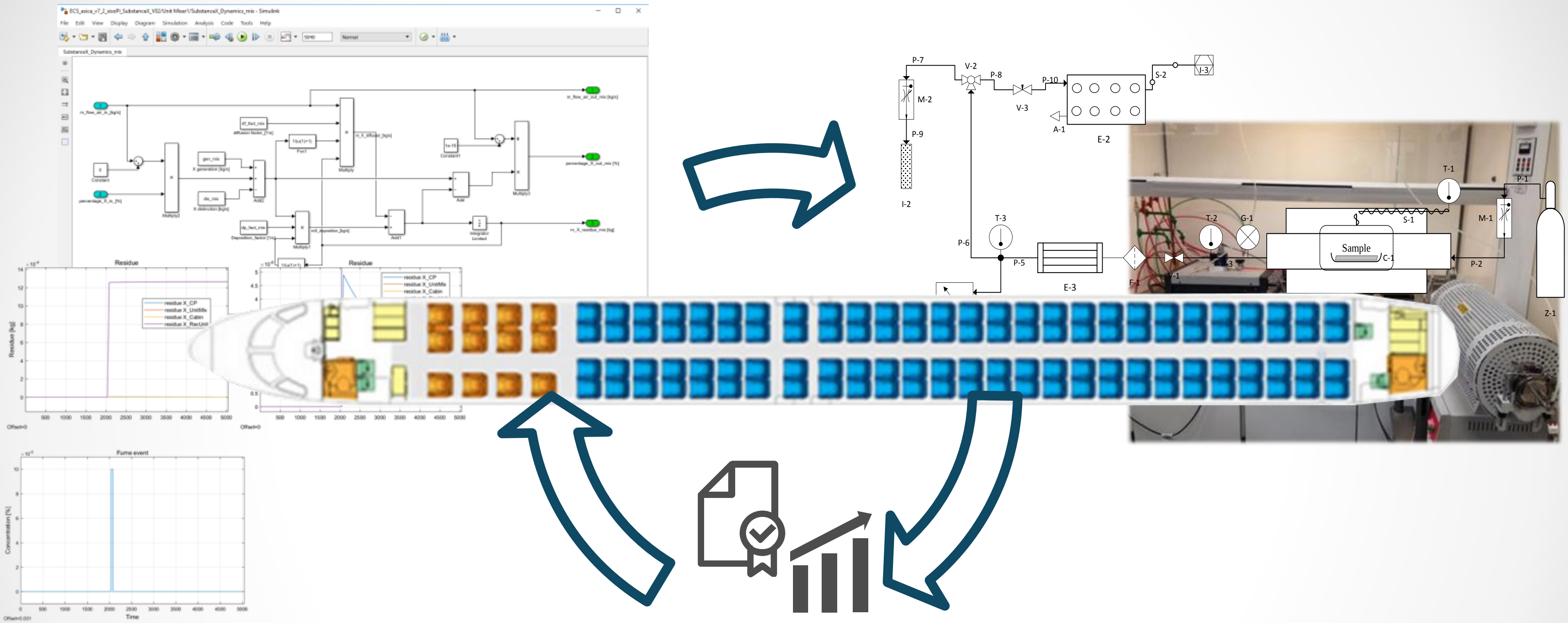
Direct Feedback

Data

Uses

- Operation: improved event detection (eg., fire); ECS management
- MRO: Operation/OEM
- Airliner/OEM: design, cabin tailoring
- Regulator: verification

IFCAS: Key enablers



Business cases (on board sensors, data use)

Standardization

Simulation and modeling coupled with experiment

Materials and substances: old and new

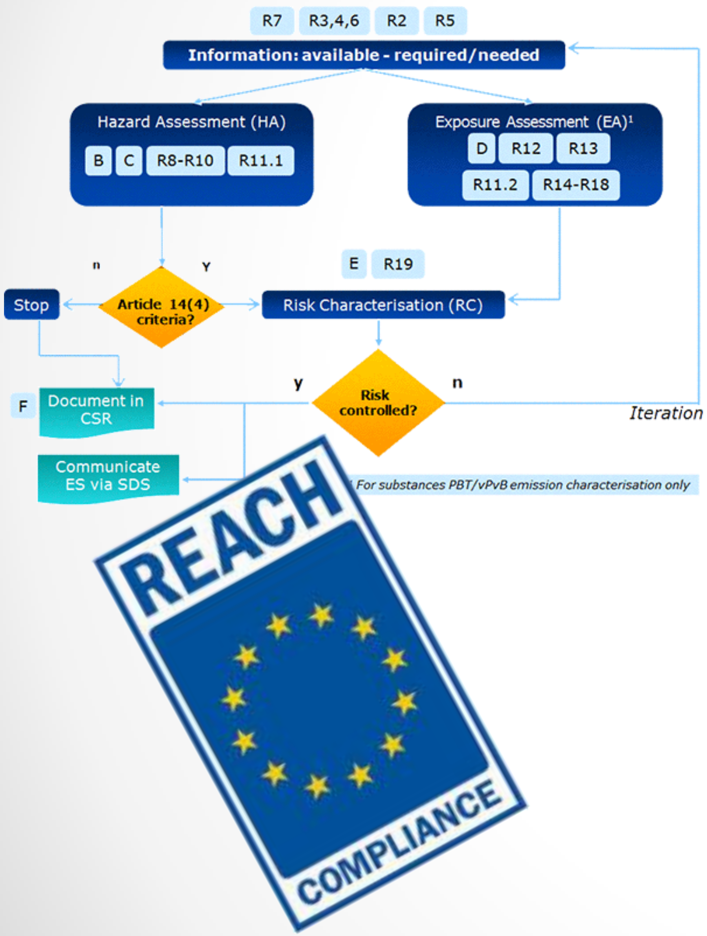
APPLICATIONS

- Structural
- Isolation: thermal, acoustic
- Furnishing
- IFE
- Cleaning

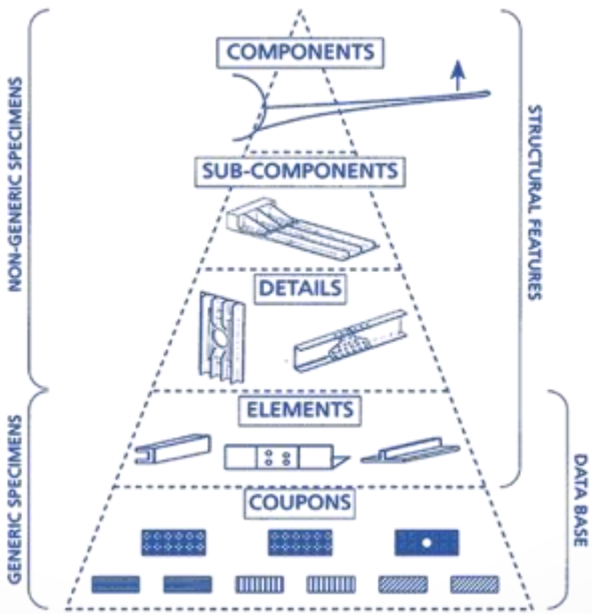
TYPES

- Composites
- Nano
- Metamaterials
- Flexible electronics
- Multifunctional

Materials and substances: old and new



NanoSafety Cluster



Modelling
Testing for aging and release (e.g, Cranfield, FSS 7.3)

Final words

- The aircraft works in a very harsh environment, cabin environment is complex: knowledge is increasing;
- Existing research shows that CAQ is good, improvement still possible (e.g., comfort);
- Different lead initiatives to clear doubts on on-board contaminants: FACTS aims for the definitive answer;
- New technology – eg sensoring, ECS, filtering – enable improvement. Clear value creation ID for adoption;

➢ **IFCAS concept proposed to contribute to CAQ improvement: follow on research needed**

Final words (2)

- Embraer pays close attention to passenger and cabin crew safety, health and comfort. It participates in dedicated working groups (eg, SAE, ASHRAE) and R&D projects (e.g., FSS, direct collaboration (BR, EU, USA), *in house*);
- Collaboration R&D with full value chain (academia, RTC, suppliers, airliners, regulators) to accelerate new technology adoption;
- Some themes for focus: sensors, standardization, aircraft efficiency, CAQ effects on comfort, …

Consortium

Stichting Nationaal Lucht- en Ruimtevaartlaboratorium
Deutsches Zentrum für Luft- und Raumfahrt
Office national d'études et de recherches aérospatiales
Centro para a Excelência e Inovação na Indústria Automóvel
Centro Italiano Ricerche Aerospaziali
Centre Suisse d'Electronique et Microtechnique SA
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Instituto Nacional de Técnica Aeroespacial
Výzkumný a zkušební letecký ústav, a.s.
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Civil Aviation Authority UK
Airbus SAS
Airbus Operations SAS
Airbus Defence and Space
Thales Avionics SAS
Thales Air Systems SA
Deep Blue SRL
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Institut Polytechnique de Bordeaux
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Sistemi Innovativi per il Controllo del Traffico Aereo

http://www.futuresky.eu/projects/safety

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