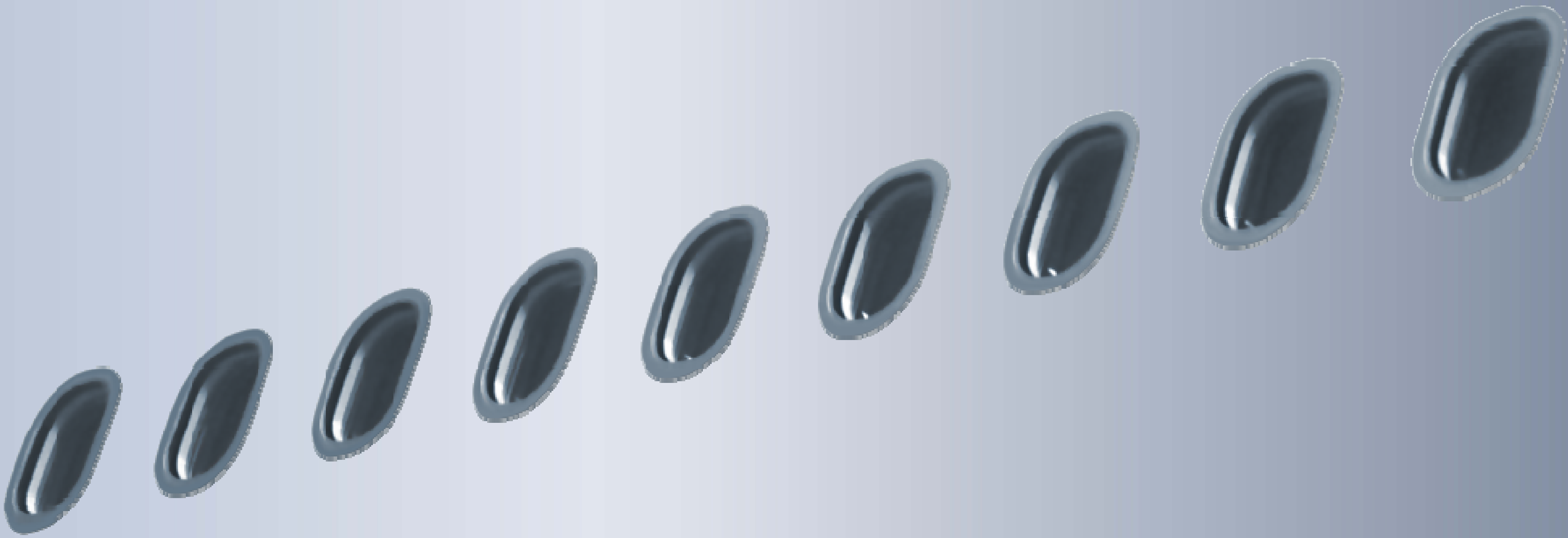


Environmental Control Systems

BG Verkehr Industriedialog 04. Juni 2013

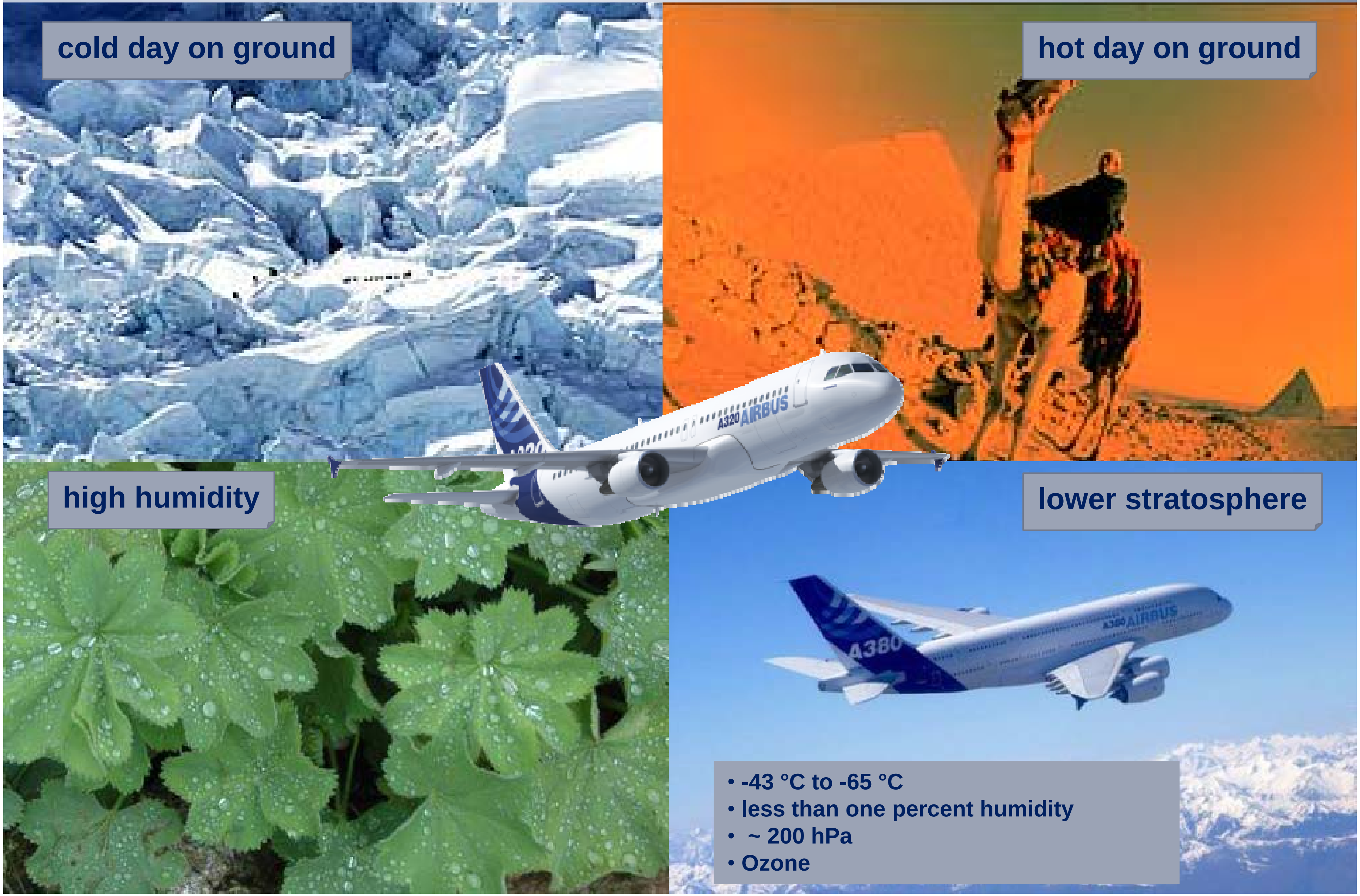
Presented by
Andreas BEZOLD / Environmental Control Systems – Air Quality

AIRBUS

Environmental Control Systems

Requirements and System Solutions

The Environment



The Requirements...

Certification requirements:

- ✓ outside air flow
- ✓ air quality (CO_2, CO, O_3, ...)
- ✓ cabin pressure-level
- ✓ cabin temperatures

…

Functional requirements:

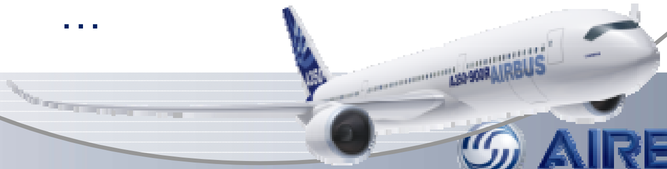
- ✓ removal of high thermal loads (passenger, avionic, IFE, galleys,...)
- ✓ independence of environment (Tcab≠Tamb)
- ✓ structural integrity (Δ P)

…

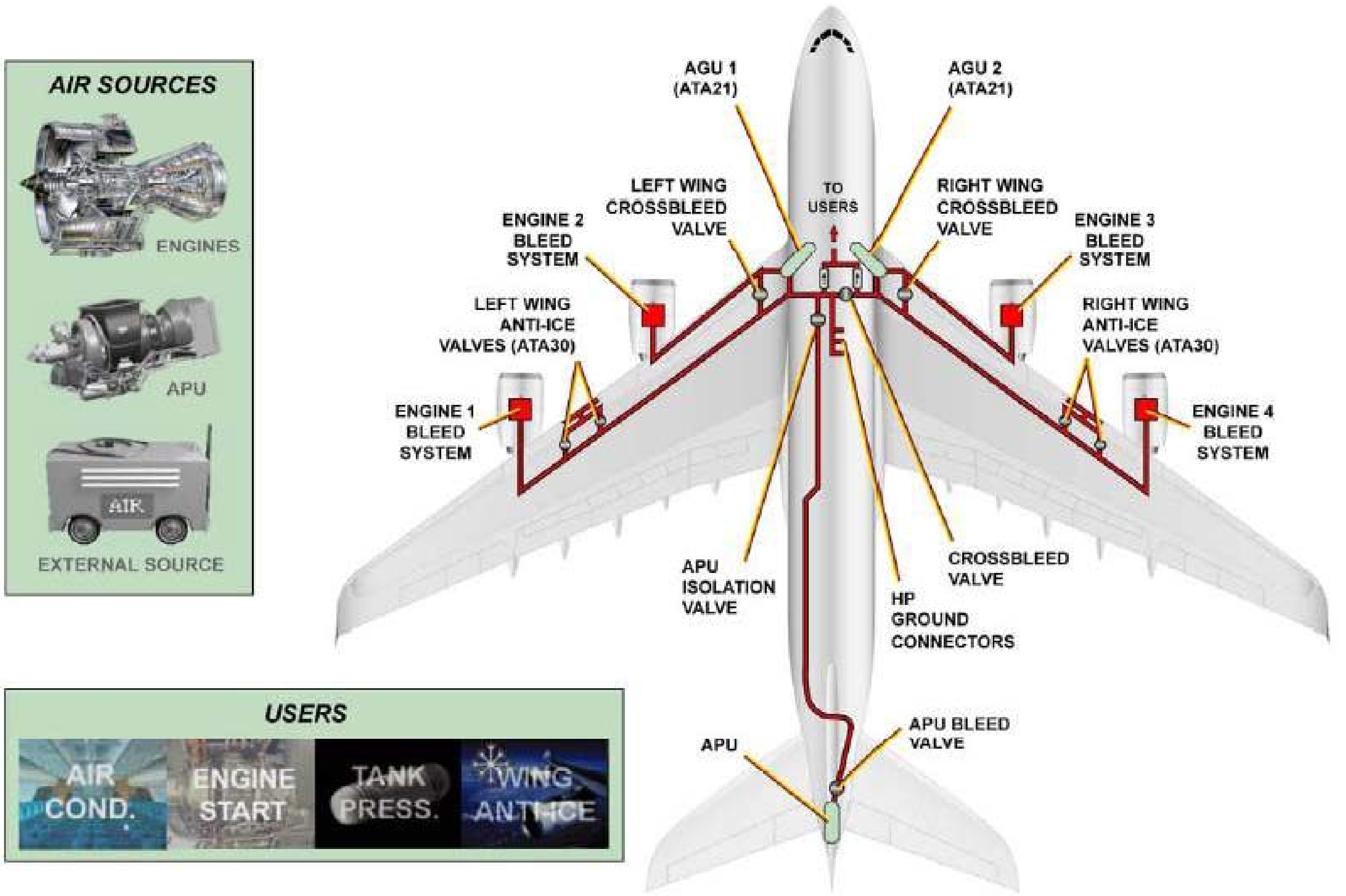
Customer requirements:

- ✓ high degree of flexibility
- ✓ comfort
- ✓ payload temperature control
- ✓ low maintenance costs
- ✓ low fuel consumption

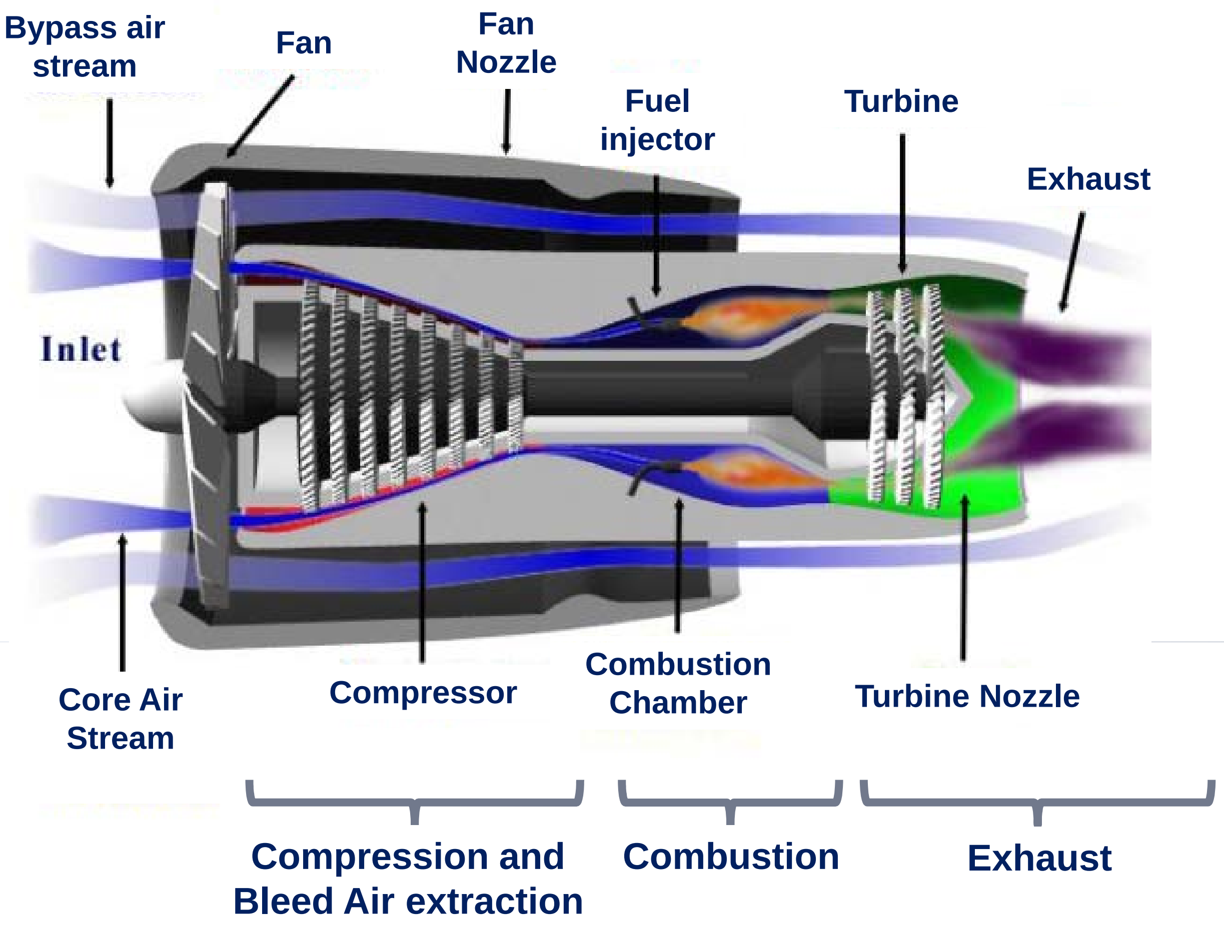
…



The Source of Pressure – The Bleed System

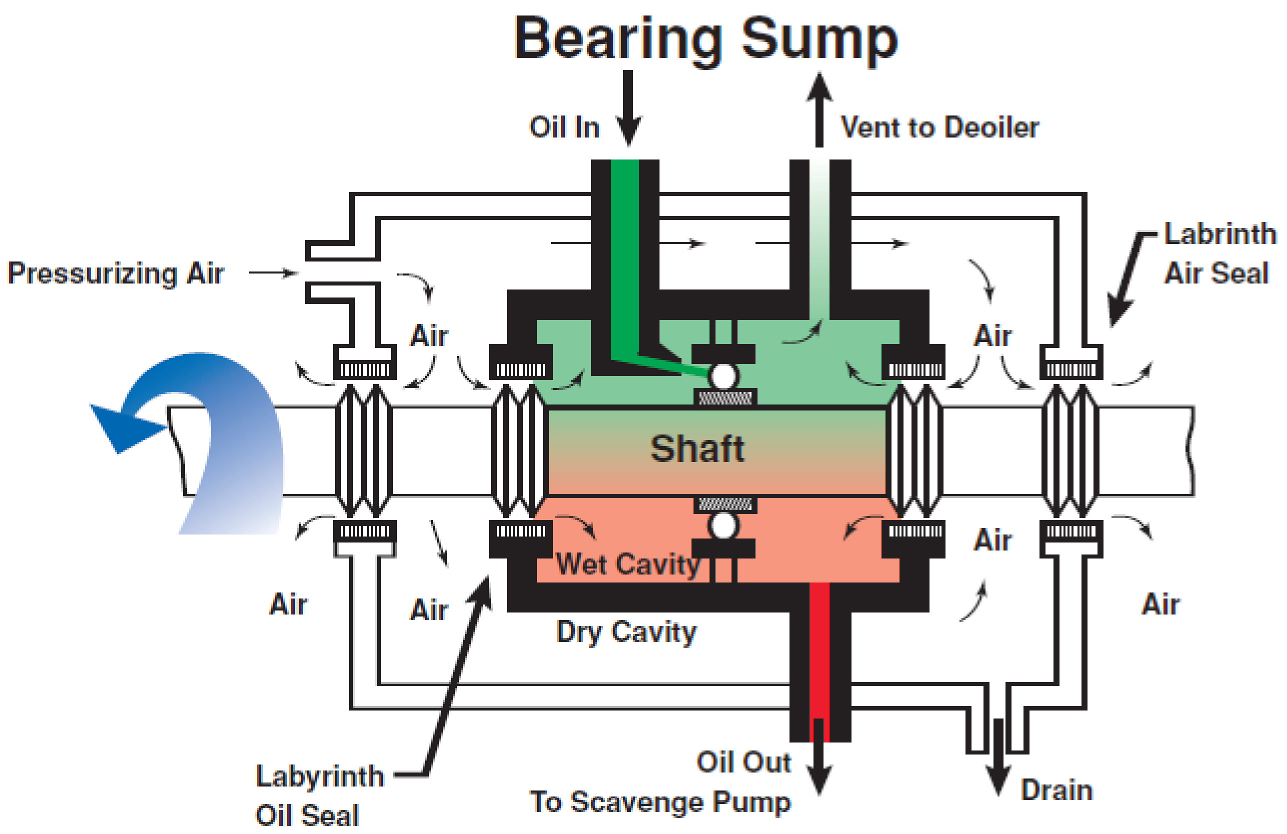


Turbofan Engine – Working Principle



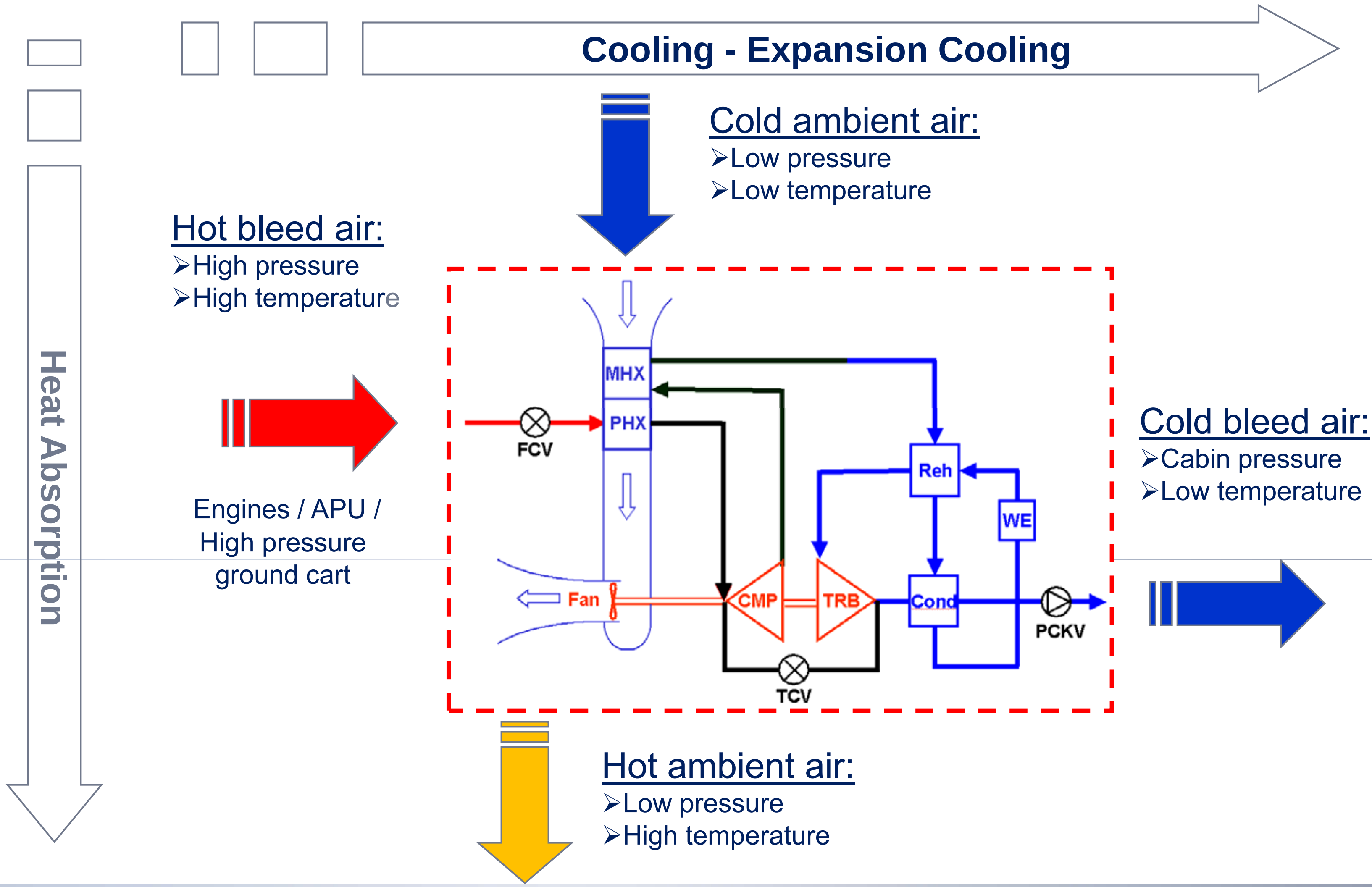
Air is taken from compressor stage UPSTREAM of the combustion chamber

Shaft Bearing Lubrication System simplified



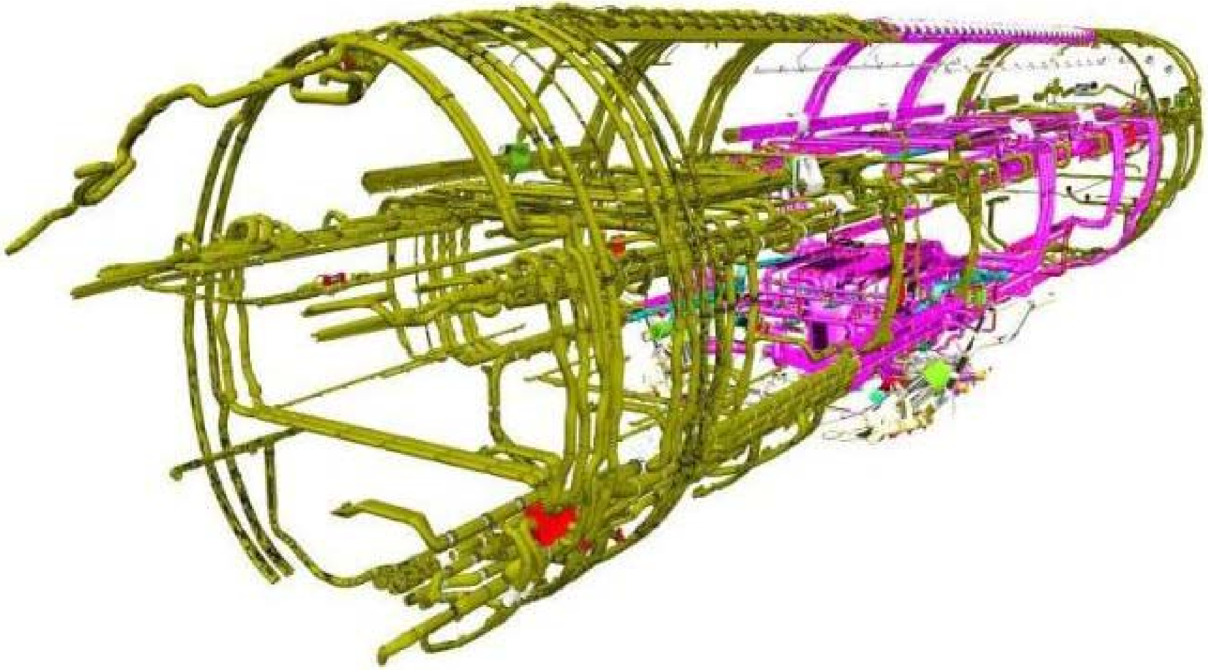
Exxon, 2009

Conditioning of Air – The Pack

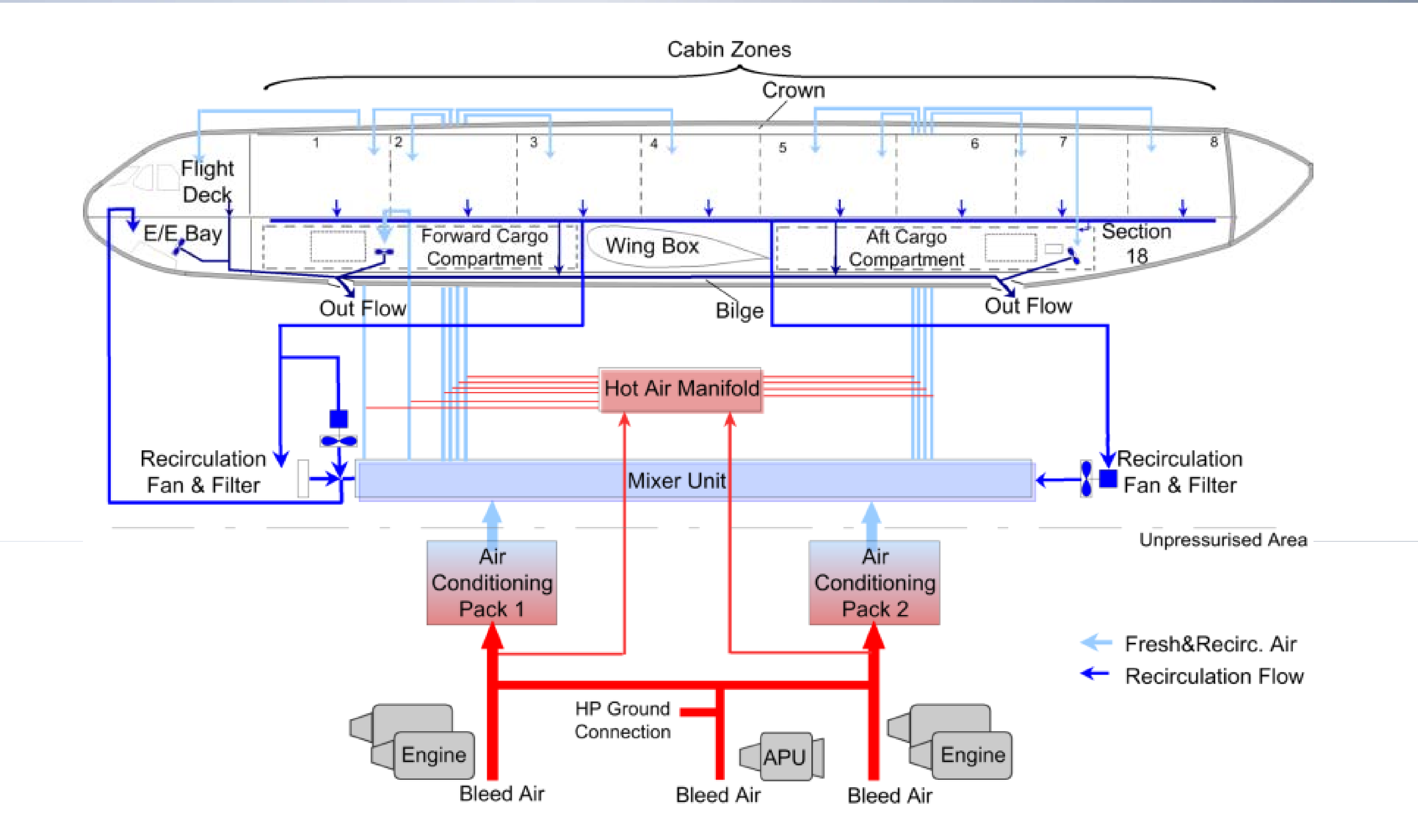


Air Distribution – The Ventilation System

- Even distribution of conditioned air throughout the fuselage
- Sizing and integration of needed blowing / extraction fans and ducting
- Sizing and positioning of air outlets
- Using mixing principle to balance airflow with temperature gradients at increased humidity



The Entire Picture



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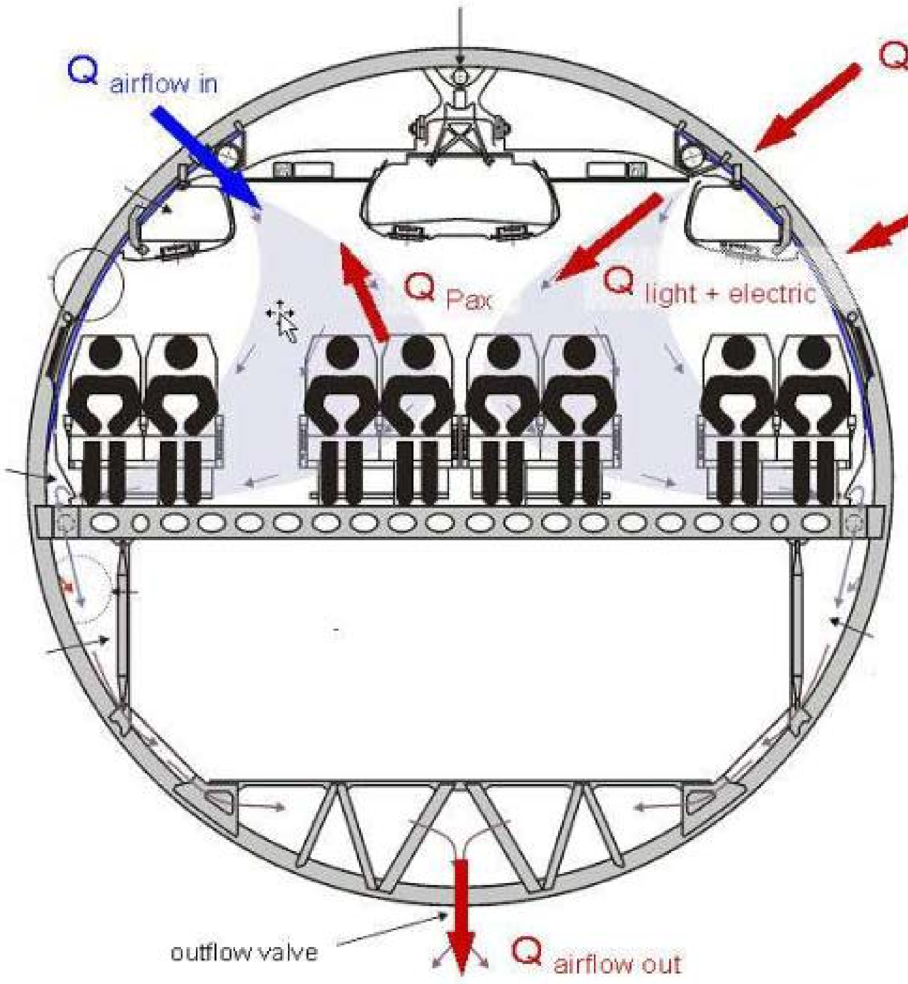
What drives ECS energy demand



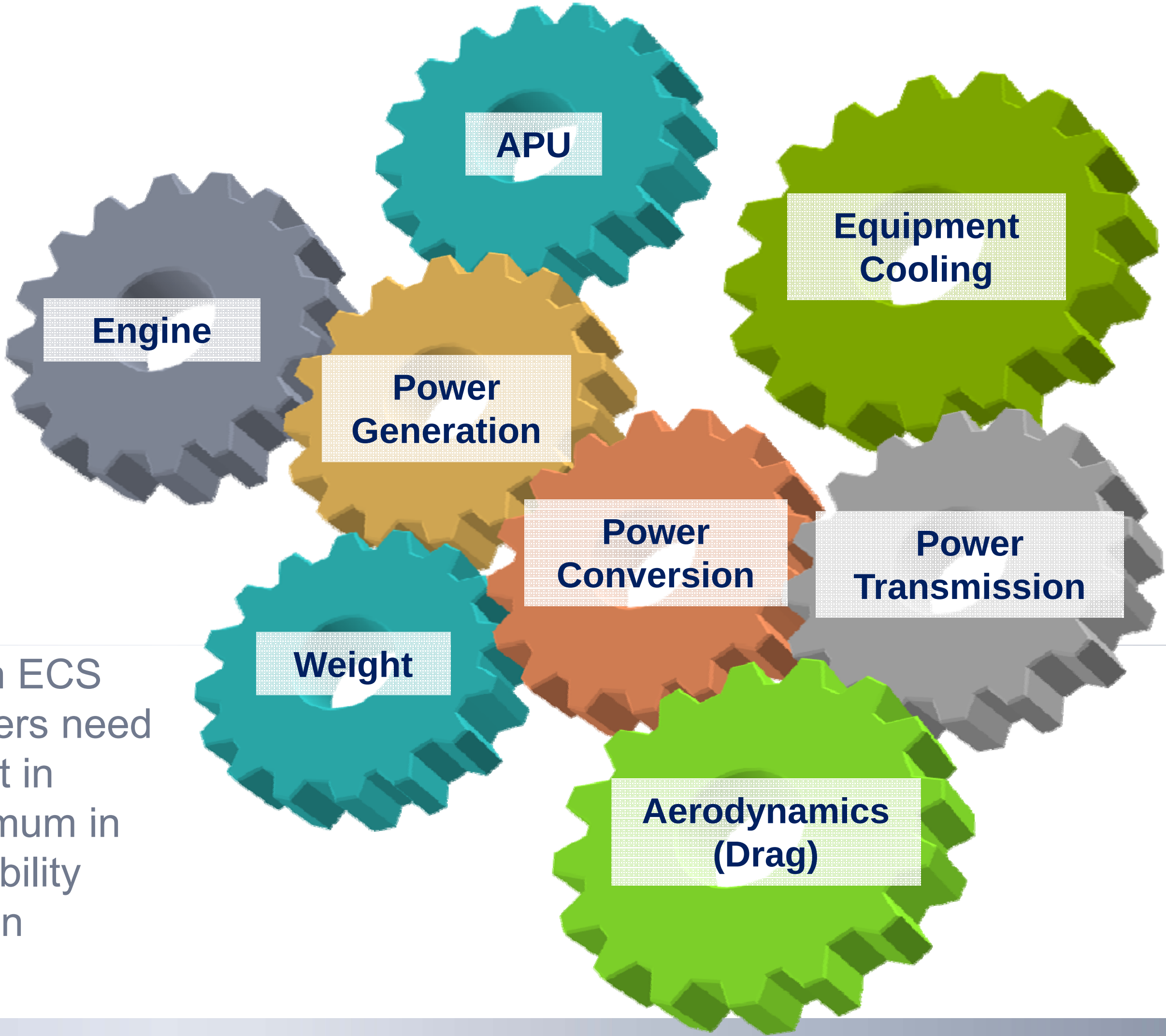
demand of cooling airflow based on cabin heat balance and air exchange determines performance of air conditioning (above minimum certified airflows) and pressurization.

Example A320 net energy demand during flight:

Cooling:	~ 20 kW
Pressure adaption:	~ 150 kW
Ventilation:	~ 3 kW

Actual consumption considerably higher

ECS Development Parameters (Assortment)



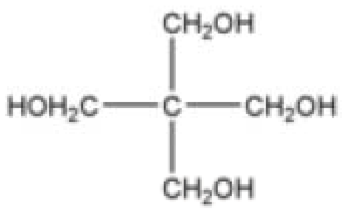
During development of an ECS concept many parameters need to be taken into account in order to assure an optimum in operational safety, reliability and energy consumption

Composition and Toxicity of Engine Oils

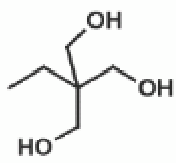
What do we know from Literature?

Engine oil…

…consist mainly of synthetic fatty acid esters of Pentaerythritol or Trimethylolpropane



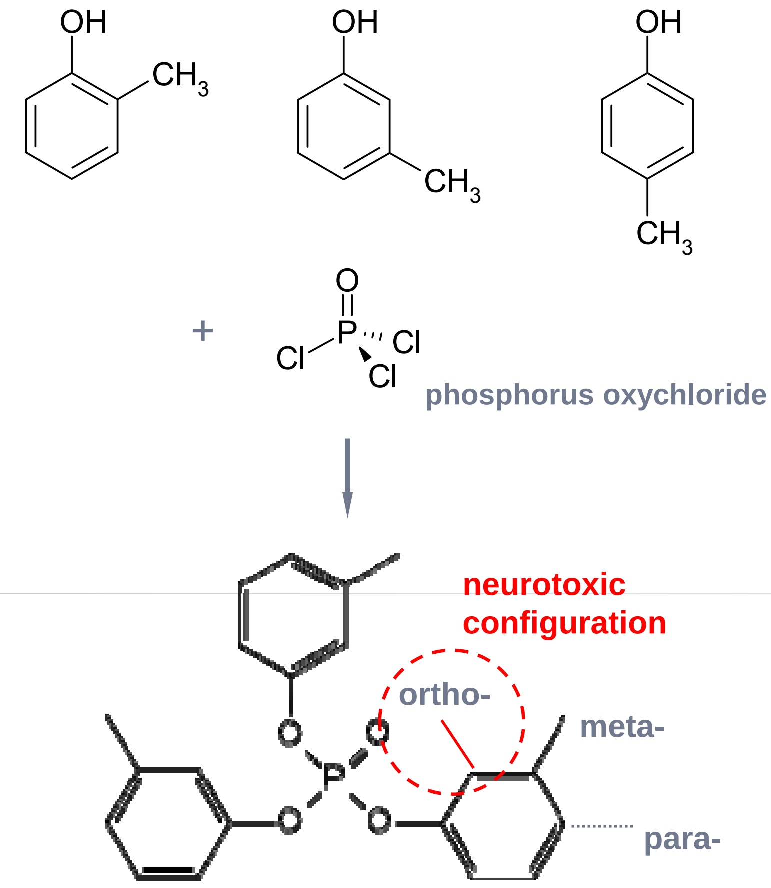
Pentaerythritol



Trimethylolpropan (TMP)

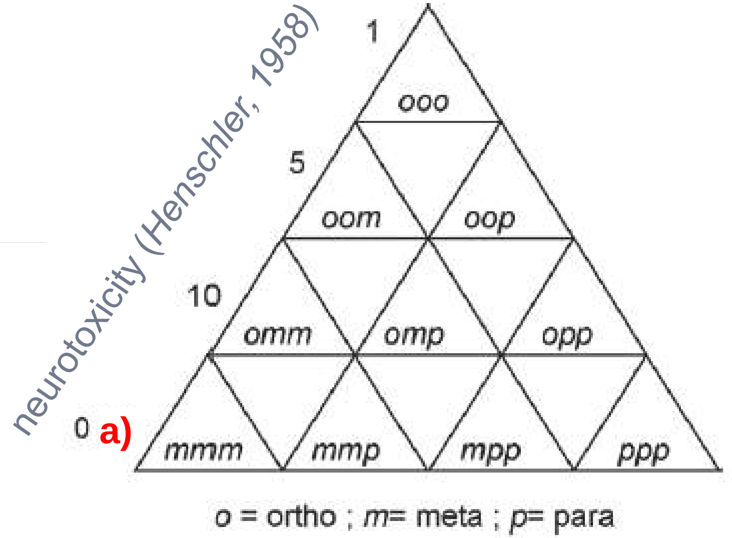
Turbine Oil	JEO Type I	JEO Type II	JEO Type III	JEO Type IV
Base alcohol Pentaerythritol	X		X	X
Trimethylolpropane		X		
Fatty acid				
Pentanoic acid	X		X	X
Hexanoic acid		X		X

TCP – Production and Isomeric Structure



Tri-cresyl-phosphate

Tri-cresyl-phosphate exists in 10 isomeric forms, depending of the position of the methyl groups. The ortho-isomers (rather their metabolic products in human bodies) are neurotoxic at sufficiently high concentration but only of vanishingly low concentration in the engine oil.

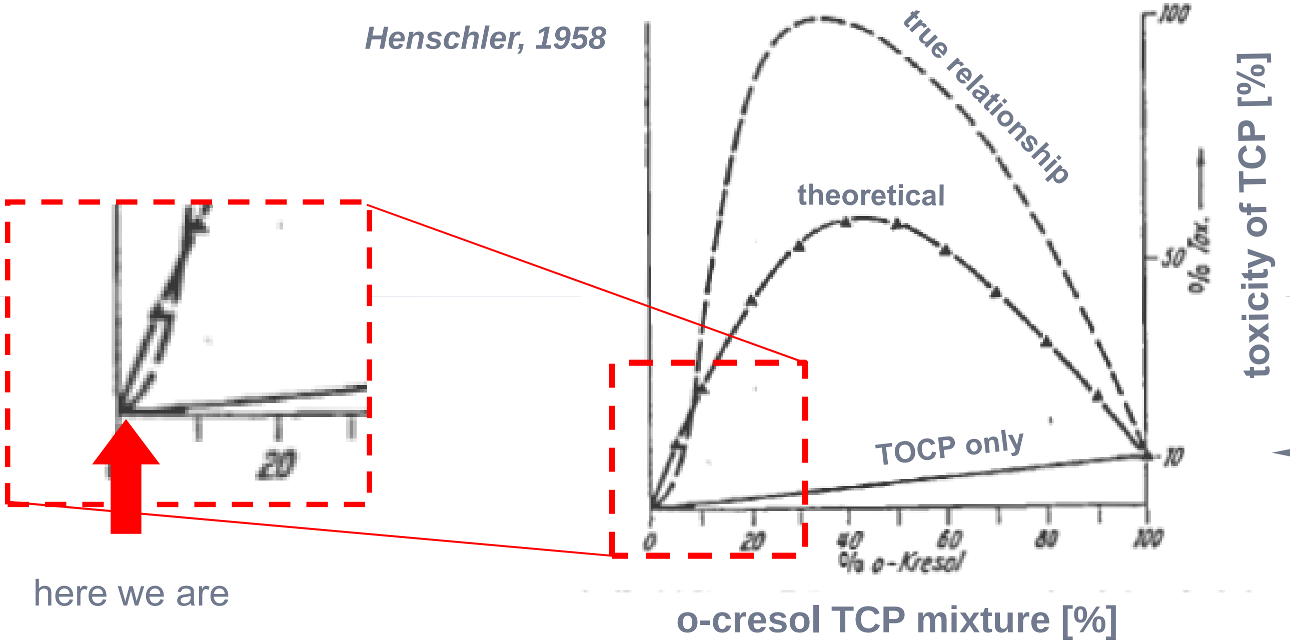


a) Henschler and other scientists could not find any symptoms even at high doses for TCP made from para- and meta-cresyls.

TCP – Toxicity in Relation to TOCP

- neurotoxicity of TCP depends on the content of ortho-isomers, which is given by the ortho-cresol concentration in the crude reaction mixture
- mono-ortho-isomers are more toxic than di- and tri-ortho-isomers
- jet engine oil contains about 2-3% TCP, which contains < 0,2 % ortho-isomers and according to Henschler is of **significantly lower toxicity than pure TOCP**

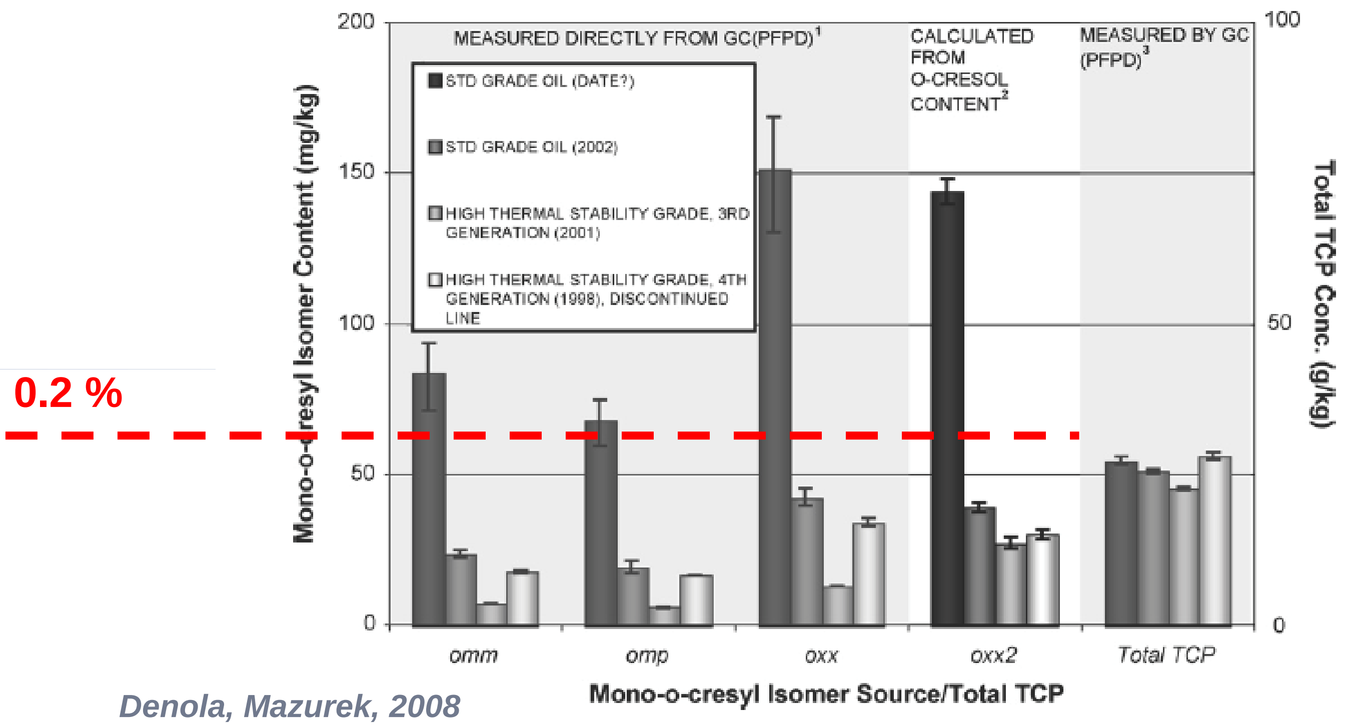
Henschler, 1958



Tri-ortho-cresyl-phosphate (TOCP)
TLV (0,1 mg/m³ TWA)
ACGIH 2001

TCP – Content in JEO in practice

- Department of Defense (Australia) determined TCP isomers in different jet engine oils from one single manufacturer
- Total TCP content 2-3%
- Total ortho-isomer concentration (< 50 ppm) below 0,2% of total TCP



Denola, Mazurek, 2008

Measurements on Aircraft

Published data on TCP

Measurements on Aircraft - TCP

Some measurements of TCP concentrations are available, some of them taken during fume and even smoke events, all of them are at concentration well below levels published as hazardous for health

Hanhela (2005): 0,4-49 µg/m³ total-TCP on military aircraft including incident with oil ingestion by APU (49 µg/m³) (Hanhela 2005)

Cranfield University (2011): 95% of 981 samples from 100 flights w/o detectable level. Max. 37 µg/m³ total-TCP for a single sample. Max 8 µg/m³ average concentration during 1 flight. Findings of TOCP far below ACGIH TLV (⚡?).

Van Netten (2009): 0,03-0,08 µg/m³ Total-TCP in BAe146 w/o incident

Solbu (2011): max. 0,29 µg/m³ total-TCP w/o incident. 5 µg/m³ on aircraft on ground with strong oil smell. Higher exposure seen at aircraft mechanics.

Denola (2011): max. 51 µg/m³ total-TCP on military aircraft with smoke event

ASHRAE (2012): ~1,5 ng/m³ m-TCP detected during one out of 63 flights

- All above studies able to clearly distinguish between 10 TCP isomers could not detect any TCP ortho-isomer in the cabin. This is quite consistent with the information we have on the composition of JEO

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Measurements on aircraft - Conclusion

- Even during oil contamination events, reported TCP levels do not exceed ACGIH TLV for TOCP
- ortho-Isomers of TCP were not reported (except by Cranfield at concentrations far below ACGIH TLV)
- This is consistent with published information on composition of Jet Engine Oils
- Inconsistencies between studies (i.e. TOCP findings) should be clarified

- Few data available on other contaminants during such event
  - No significantly increased VOC concentration during smell on ground *(Solbu, 2011)*
  - No significantly increased CO concentration during oil smell incident (visible haze) on ground (*van Netten, 1998*)

- ASHRAE 1262 TRP results on air quality on 83 commercial flights did not contain fume or smoke events. Air quality stated being comparable or better than in offices, schools or residences with few exceptions. Several compounds related to passengers.

Airbus Air Quality Measurements

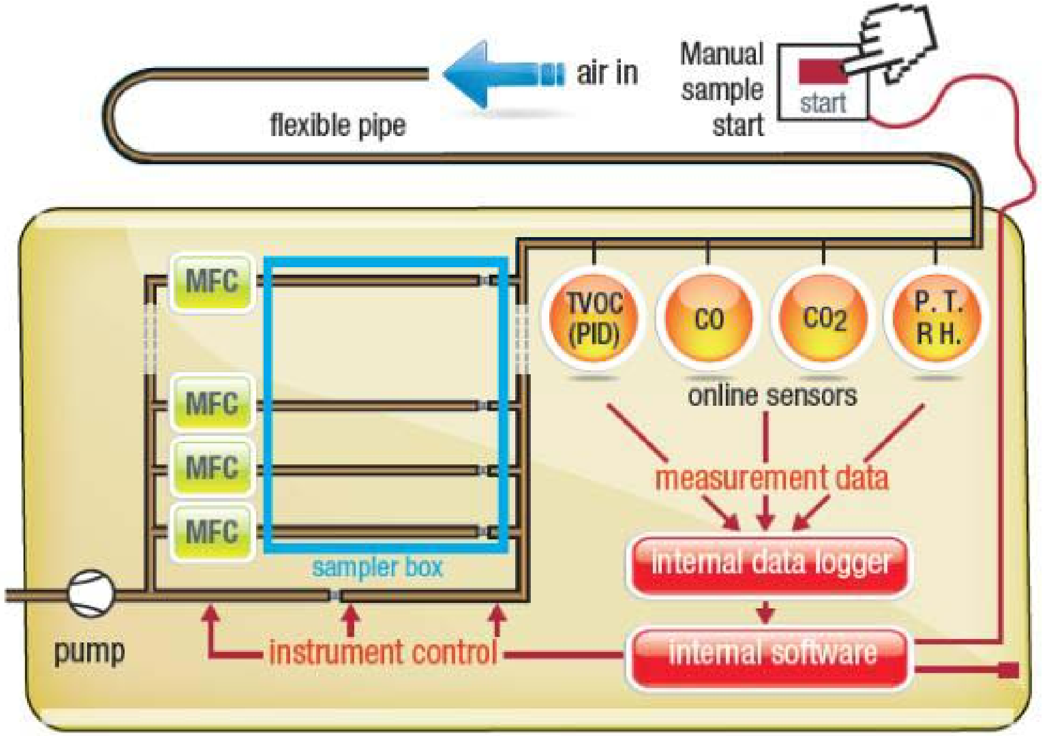
Measurement Technologies

- Online measurement with PTR-MS
  - In order to trace contaminants in a high temporal resolution
  - Correlate trace contaminants with aircraft system data
- Component Class Specific Adsorbent Cartridges/Filters
  - Analyze and identify chemical components
  - Match identified components with molecular mass data from PTR-MS
- Particulate Measurement (Aerosol spectrometer)
  - In case of non gaseous contamination
  - If possible determine organic load of particulate matter

Monitoring – PTR-MS-TOF on aeroplane

Integrative Sampling Methods (Fraunhofer IBP)

- Integrated concept with sensors and adsorbent tubes installed in trolley sized housing
- Removable box with quick connections containing sampling tubes (up to 32)



Conclusion

- Cabin Air Quality remains a high priority topic for the industry
- Cabin odour can occur and may be caused by many sources including engine related sources, but this does not necessarily indicate a high concentration of contaminants, either toxic or non-toxic
- Reported in-service events are difficult to investigate. The links between the reported cabin air quality event, the potential source and a confirmed medical condition remains difficult to establish
- However recognizing the industry concerns, Airbus and other stakeholders are committed to ongoing research programmes

PTR-MS-TOF - Next Generation

Thank you !