Design and Development of an Aircraft Cabin Air Contaminant Sensor
Presentation to SAPOE 2015, Madrid
Agenda

- **Company Overview**
- **Summary of Issue: Bleed Air Contamination**
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  - CADORS Report & ICAO Annex 13
  - Potential Sources of Contamination & Statement of Risk
  - Regulatory Overview: TC AWM 525.831 & 525.832
  - Rate of Occurrence: Indoor Air 2015 (KSU Study)
- **Design and Development of Aircraft Cabin Air Contaminant Sensor**
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- **Next Steps and Discussion**
- **Partners and Acknowledgements**

Omer Majeed, P.Eng., Specific Range Solutions Ltd.
October 16th, 2015
Overview of Specific Range Solutions Ltd.

- We develop EFB applications for airlines and are engaged in R&D to develop advisory systems for the commercial aviation market.
- We provide engineering services and solutions to airlines and to one aircraft air system OEM.

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- Currently two technical staff: Omer Majeed and Tamara Tardif.
- Founded in December 2008.
- Based in Ottawa, Ontario.
Problem Overview: Bleed Air System & Air Conditioning System
Problem Overview: Bleed Air Contamination (Aviation Press)

➢ Aviation Week, October 8, 2012: Lufthansa pushing for means to monitor cabin air quality following passenger and crew reports of cabin fumes on-board Airbus A380 and A319.

➢ Flight International, October 23-29, 2012: German transport minister Peter Ramsauer has asked EASA (European Aviation Safety Agency) to take action, citing 74 reports of pyrolised oil fume incidents on German carriers, 9 deemed serious.

➢ Germanwings Airbus A319 incident: On approach to Cologne in December 2010, both pilots reported being close to losing consciousness.

➢ Flight International, April 16, 2013: German pilots' union Vereinigung Cockpit, estimates that on average there are about 10 fume events each week across the entire German airline fleet.

➢ Flight International, April 16, 2013: Per July 17, 2012 Request for Information: "The Federal Aviation Administration seeks information…related to effective air cleaning technology and sensor technology for the engine and auxiliary power unit bleed air supplied to the passenger cabin and flight deck of a pressurised aircraft".

Omer Majeed, P.Eng., Specific Range Solutions Ltd.
October 16th, 2015
Problem Overview: Bleed Air Contamination (CADORS)

TCCA CADORS 2014Q0964: Reported occurrence on an Air Canada Embraer E190 flight from Montreal (CYUL) to Calgary (CYYC) on May 27th, 2014.

Per ICAO Annex 13 – Flight crews only need to report smoke or fire.
Problem Overview: Bleed Air Contamination (Potential Sources & Risk)

Potential sources of bleed air contaminants/fumes entering aircraft cabin:

- Engine oil (contains TAP’s: triaryl phosphates / TCP’s: tricresyl phosphates)
- Hydraulic fluid (Skydrol – contains organophosphate ester which is temperature and fire resistant)
- Engine & APU exhaust on ground
- Jet fuel (Jet A)
- De-icing / anti-icing fluid (glycol)
- Residues on new bleed equipment (valves, heat exchangers, ACM’s and HP ducting)

Statement of risk:

- Bleed air contaminants that enter the aircraft cabin represent a risk to the health and safety of crews and passengers depending on the molecular composition, concentration and duration of exposure.
- Most transport category aircraft are equipped with conventional bleed air systems, Boeing 787 excluded.
Problem Overview: Bleed Air Contamination (Regulations)

Transport Canada AWM 525.831 Ventilation > 10E-5/FH per FAA AC 25.1309-1A

(a) Under normal operating conditions and in the event of any probable failure conditions of any system which would adversely affect the ventilating air, the ventilation system must be designed to provide a sufficient amount of uncontaminated air to enable the crew-members to perform their duties without undue discomfort or fatigue and to provide reasonable passenger comfort. For normal operating conditions, the ventilation system must be designed to provide each occupant with an airflow containing at least 0.55 pounds of fresh air per minute.

(b) Crew and passenger compartment air must be free from harmful or hazardous concentrations of gases or vapours. In meeting this requirement, the following apply:

(1) **Carbon monoxide** concentrations in excess of one part in 20,000 parts of air are considered hazardous. For test purposes, any acceptable carbon monoxide detection method may be used.

(2) **Carbon dioxide** concentration during flight must be shown not to exceed 0.5 percent by volume (sea level equivalent) in compartments normally occupied by passengers or crew members.
Problem Overview: Bleed Air Contamination (Regulations)

Transport Canada AWM 525.832 Cabin Ozone Concentration

(a) The aeroplane cabin ozone concentration during flight must be shown not to exceed:

(1) 0.25 parts per million by volume, sea level equivalent, at any time above flight level 320; and

(2) 0.1 parts per million by volume, sea level equivalent, time-weighted average during any 3-hour interval above flight level 270.

(b) For the purpose of this section, "sea level equivalent" refers to conditions of 25°C and 760 millimetres of mercury pressure.
Problem Overview: Bleed Air Contamination (Rate of Occurrence)

Technical Paper: *Characterization of the frequency and nature of bleed air contamination events in commercial aircraft*

M. Shehadi, B. Jones, M. Hosni
Mechanical and Nuclear Engineering Department,
Kansas State University, Manhattan, KS, USA
Indoor Air 2015 - 2015 John Wiley & Sons A/S. Published by John Wiley & Sons Ltd

Bleed air contamination events are estimated to occur at an average rate of 2.1 events per 10,000 commercial flights based on data from the following databases. With one aircraft model, rate of 7.8 events per 10,000 flights observed.

- Service difficulty reports (SDR) on the U.S. FAA online database
- Aviation Safety Reporting System (ASRS) on the NASA online database,
- United States Department of Transportation (USDoT) website
- Bureau of Transportation Statistics
- Research and Innovative Technology Administration (FAA), 2012; BTS, 2013
- Aviation Safety Reporting System (ASRS), 2012.
Design & Development of Sensor: First Iteration

Specific Range Solutions Ltd. approached Carleton University’s Dept. of Electronics in June 2014 and proposed a project. SRS reached out to the NRC for testing expertise.

High-Level Functional Specification (TRL 4):

- Detection of CO$_2$ in a lab environment
- Detection tri-cresyl phosphate (TCP) in a lab environment
- Display of measurements
- Wireless transmission of data

[CO$_2$ Absorption Spectrum Graph]
Design & Development of Sensor: First Iteration

- First prototype was designed and tested during 2014-15 academic year:

- Device successfully tested for TCP at National Research Council on March 20th, 2015:
Design & Development of Sensor: Second Iteration

Specific Range Solutions Ltd. and Carleton University’s jointly submitted an application for NSERC Engage grant. Collaboration with Xogenus for hardware design and NRC for testing.

High-Level Functional Specification (TRL 5):

- Operating environment: Cabin altitude of 0 to 8,000 ft, temperature range of 15°C to 35°C, relative humidity of 0% to 40%.
- Detection tri-cresyl phosphate (TCP) in a lab environment to 60 ppb
- Detection of CO in a lab environment
- Detection of CO₂ in a lab environment
- Detection of O₃ in a lab environment
- Display of measurements
- Recording of data
Design & Development of Sensor: Second Iteration
Next Steps and Discussion

Next Steps:
- Calibration testing of second prototype at NRC (Fall 2015)
- Testing of second prototype at NRC (Fall 2015)
- Analysis of results.
- TRL 5 exit review and TRL 6 readiness analysis
- Patent search and patent filing

Discussion:
- Technology road map: Device to support maintenance and engineering troubleshooting to full-time monitoring in cockpit and cabin to integration with aircraft air system via full qualification and certification
- Interest and support from airlines?
Project Partners and Acknowledgements

**Project Partners:**
- Prof. Winnie Ye of Carleton University’s Department of Electronics.
- Chris Seligy of Xogenus
- Dr. Paul Lebbin and Dr. Doyun Won of the National Research Council of Canada
- Dan Trudeau of NRC’s Industrial Research Assistance Program

**Acknowledgements:**
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- NRC’s Industrial Research Assistance Program for the R&D funding grant to support testing of second prototype.

*Thank you for your time and attention.*
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