High Performance Gas Expansion System for Halon-freE CargO Hold Fire Suppression SYSTEM (ECOSYSTEM)

Evaluation of Nitrogen as a Replacement for Halon 1301 in Cargo

10th Triennial International Aircraft Fire and Cabin Safety Research Conference, Atlantic City, NJ, USA
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Clean Sky 2 – AIRFRAME-ITD

Consortium Partners: Collins Aerospace

Topic Manager: AIRBUS

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AGENDA

- Project Overview
- ECOSYSTEM Objectives
- Cargo Compartment Set-up
- O_2 Sensor Locations and Demonstrator Installation
- Testing Results
  - O_2 Concentration
  - Pressure rise
- Simulation Results and Comparsions

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ECOSYSTEM OVERVIEW

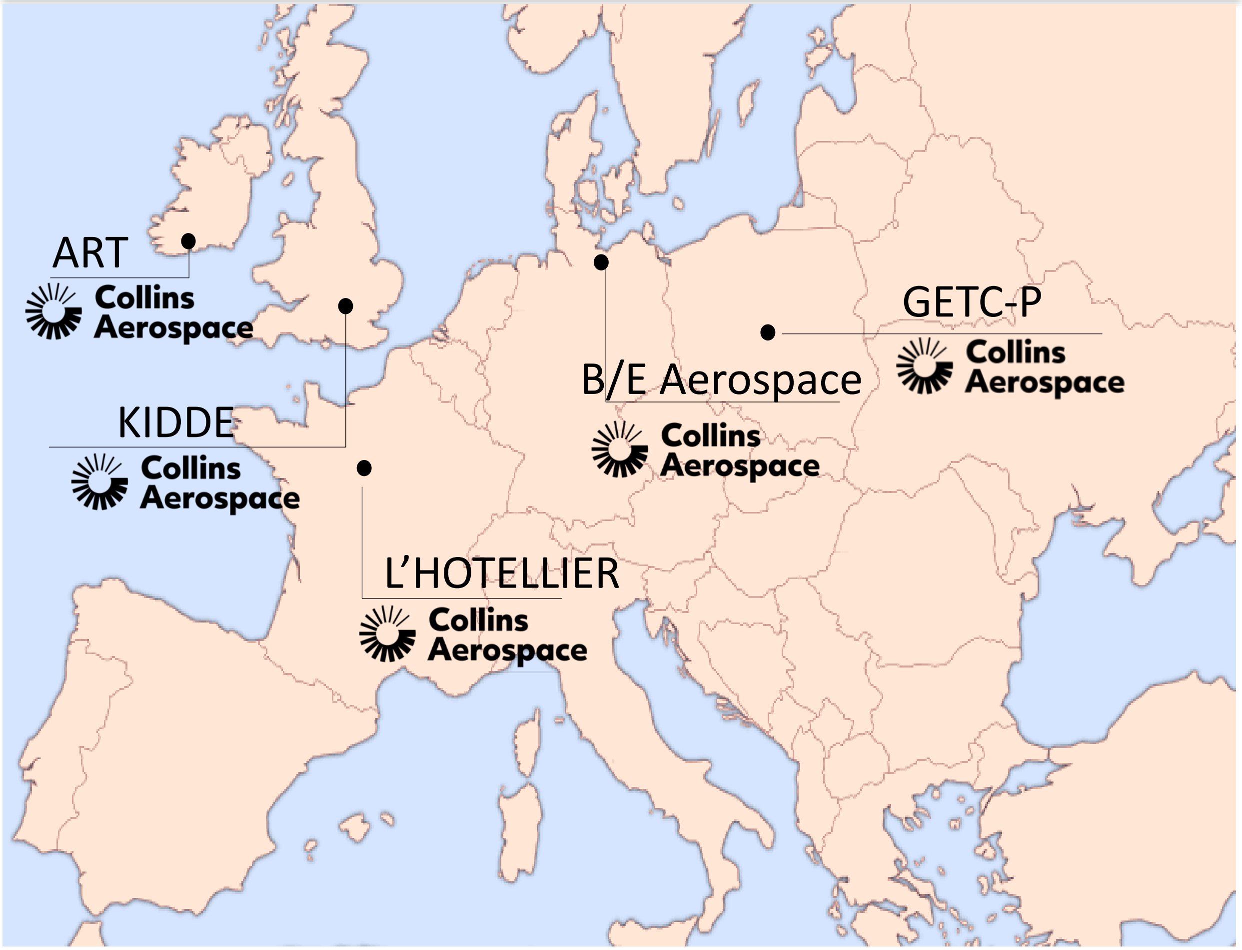
BACKGROUND

- ECOSYSTEM is an EU funded Clean Sky 2 project
- Project started October 2019 and completed March 2022
- Max EU contribution of k€699
- Project effort 74 person months
- Topic Leader – Airbus

SCOPE AND POSITIONING

- Develop an environmentally friendly and economically viable halon-free cargo hold fire suppression system
- TRL 5 demonstration in relevant environment at Fraunhofer facility

Consortium Partners



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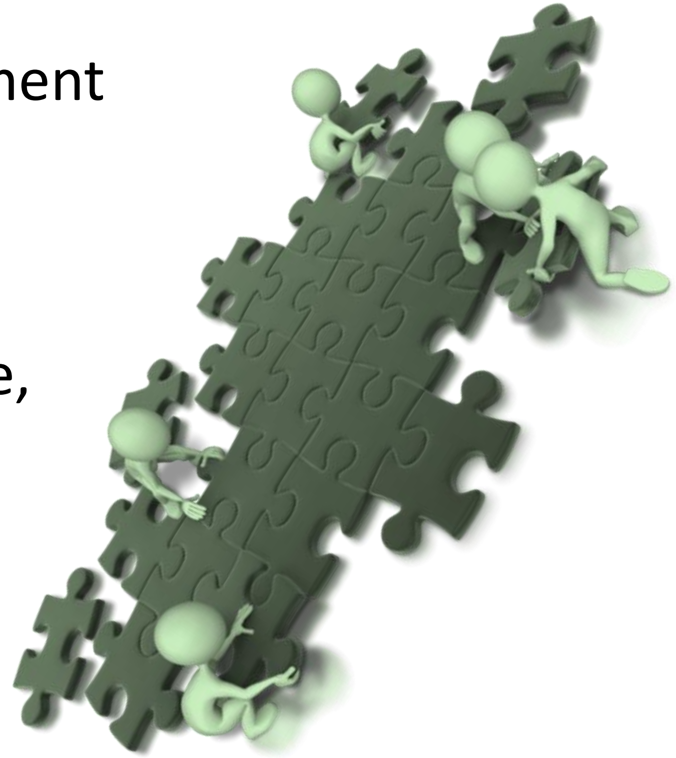
ECOSYSTEM OBJECTIVES

PROJECT OBJECTIVES:

- Develop requirements and KPIs with the topic manager
- Develop and assess system architecture options with respect to optimal placement and integration of components into demonstrator
- Design system components
- Perform trade studies to evaluate component options based on weight, volume, safety impact, certification complexity
- Perform a thorough safety/risk analysis at system level
- Model performance of demonstrator using CFD and stress analysis
- Characterize system performance at component and system level
- Test prototype at Fraunhofer Institute (Holzkirchen, Germany) and evaluate its performance



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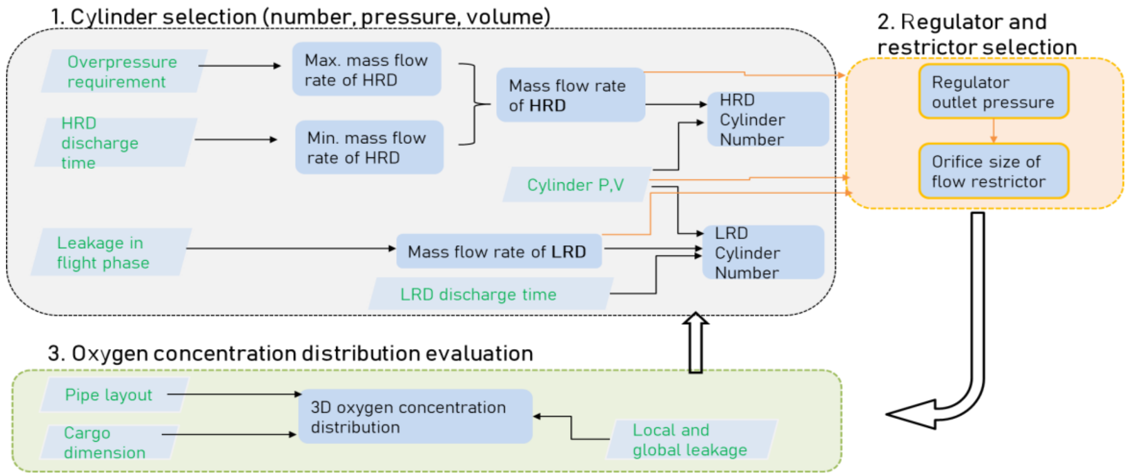
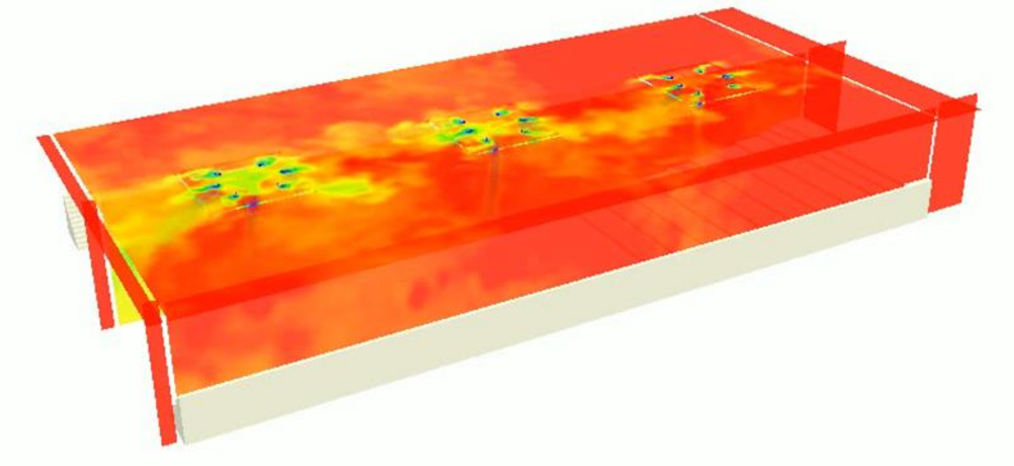
RECAP OF PREVIOUS WORK

- This project was presented at FAA April 2021 Meeting:
  - ➢ Demonstrator components
  - ➢ System design modelling process and approach
  - ➢ Modelling for component selection (cylinder, flow rate, regulators, restrictor)
  - ➢ CFD modelling of demonstrator performance at all flight phases
- This presentation will cover the testing results obtained at Fraunhofer and comparison of modelling and testing results.

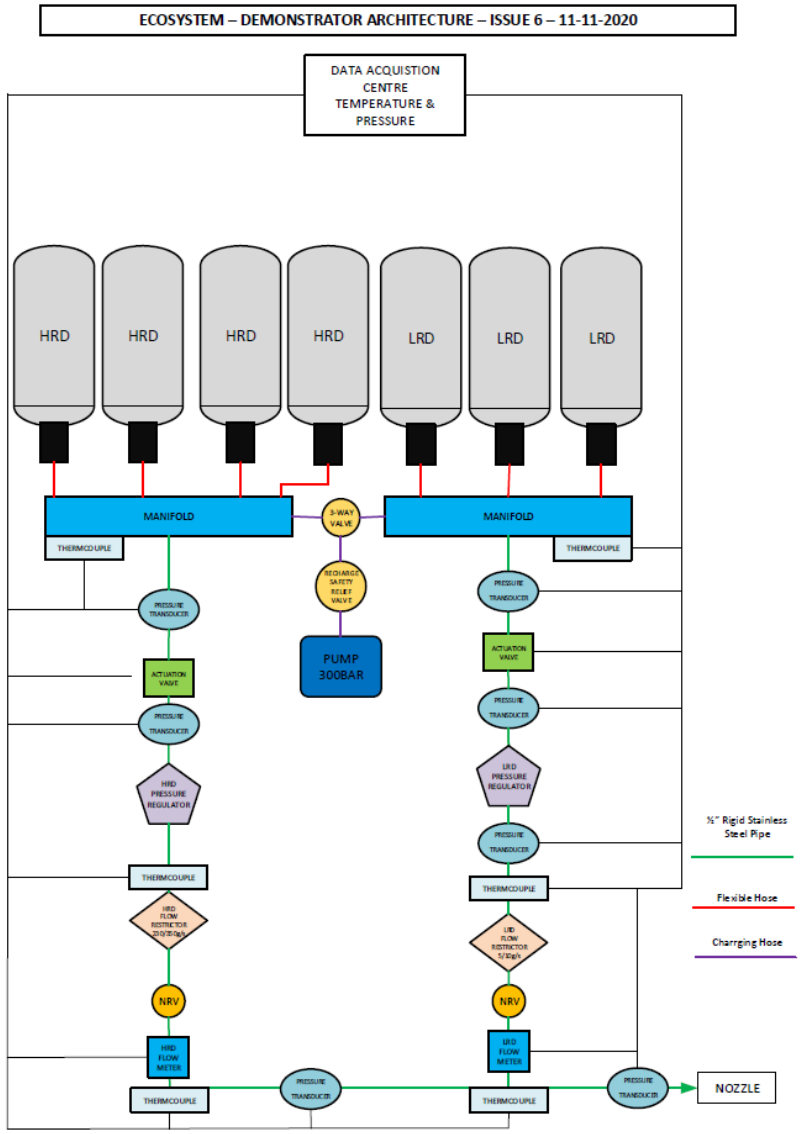




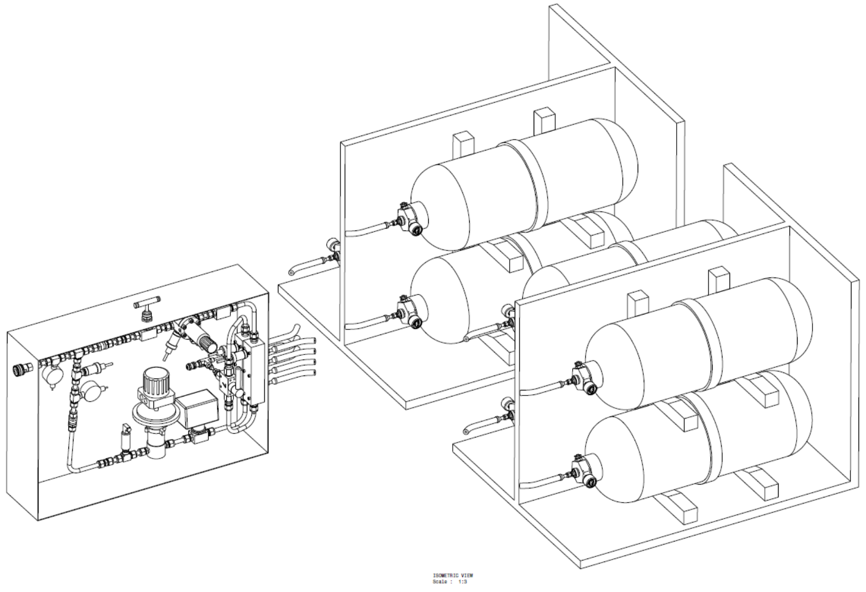
https://www.fire.tc.faa.gov/pdf/systems/April21Meeting/Chattaway-0421-ECOSYSTEM.pdf

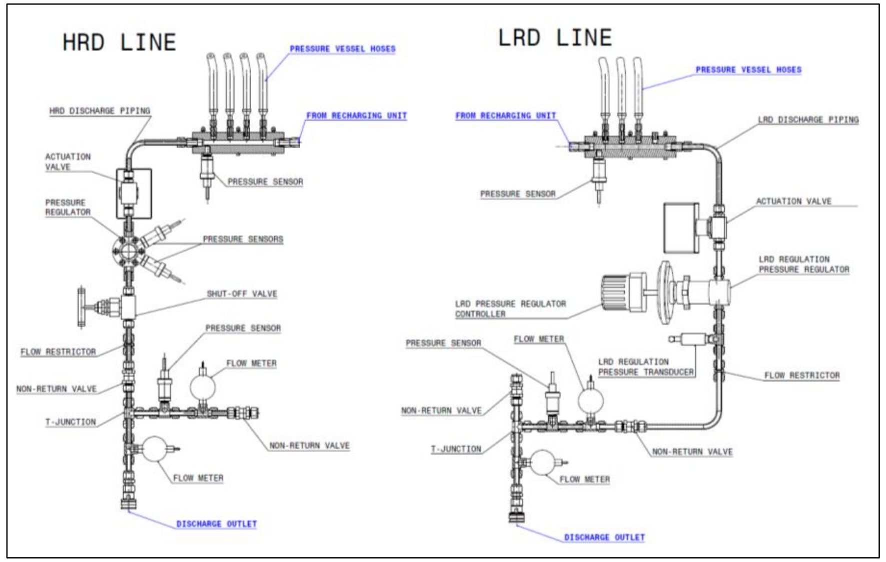
ECOSYSTEM Demonstrator

System Architecture

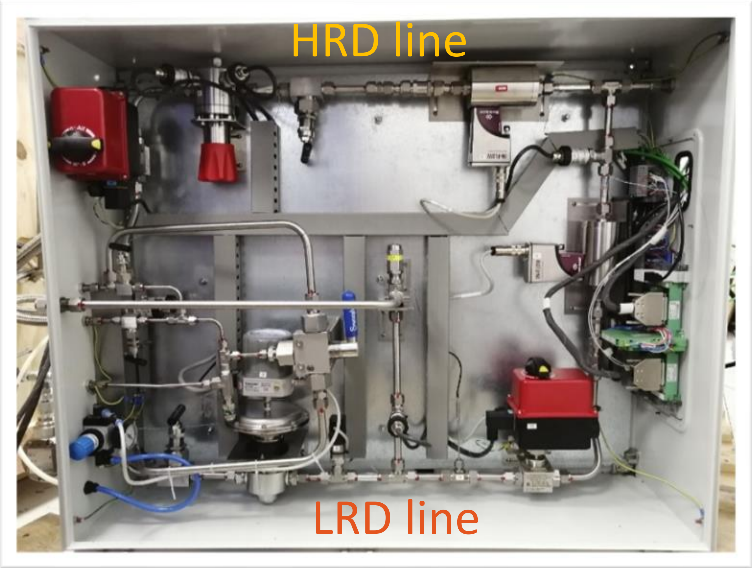


Final Design





Prototype



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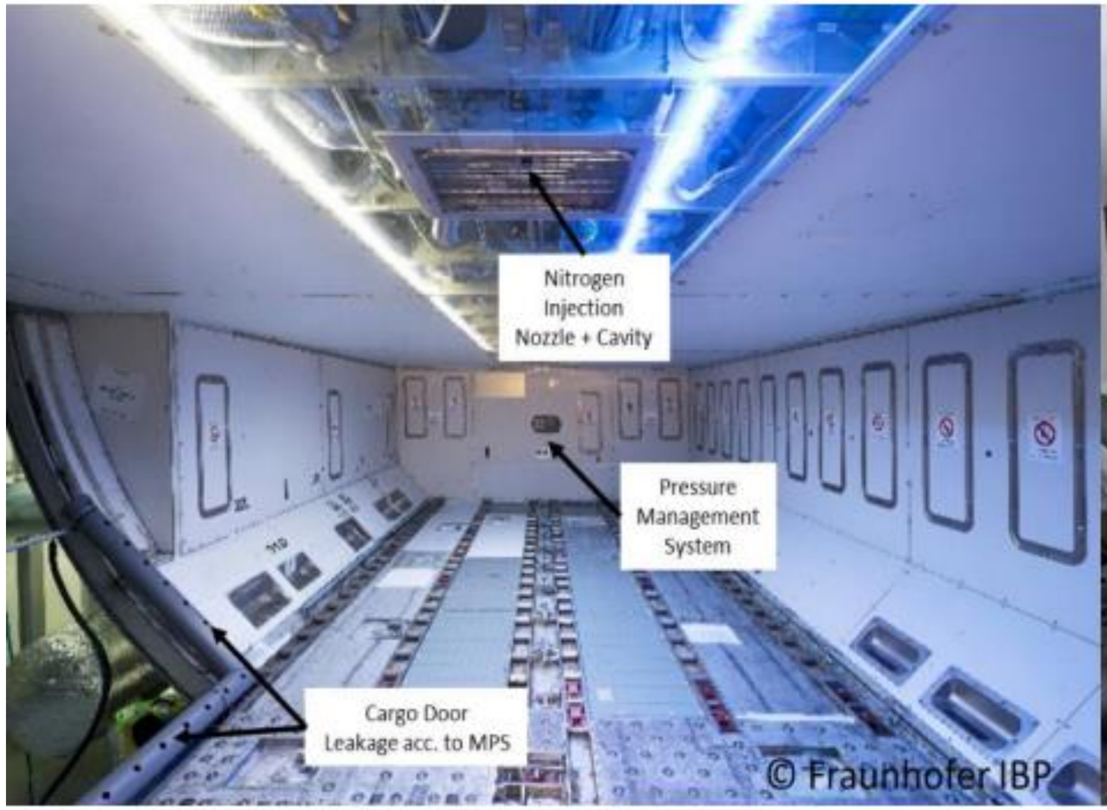
FHG CARGO COMPARTMENT SET-UP

Cargo hold modification: from A310 to required volume

Original A310 Cargo hold

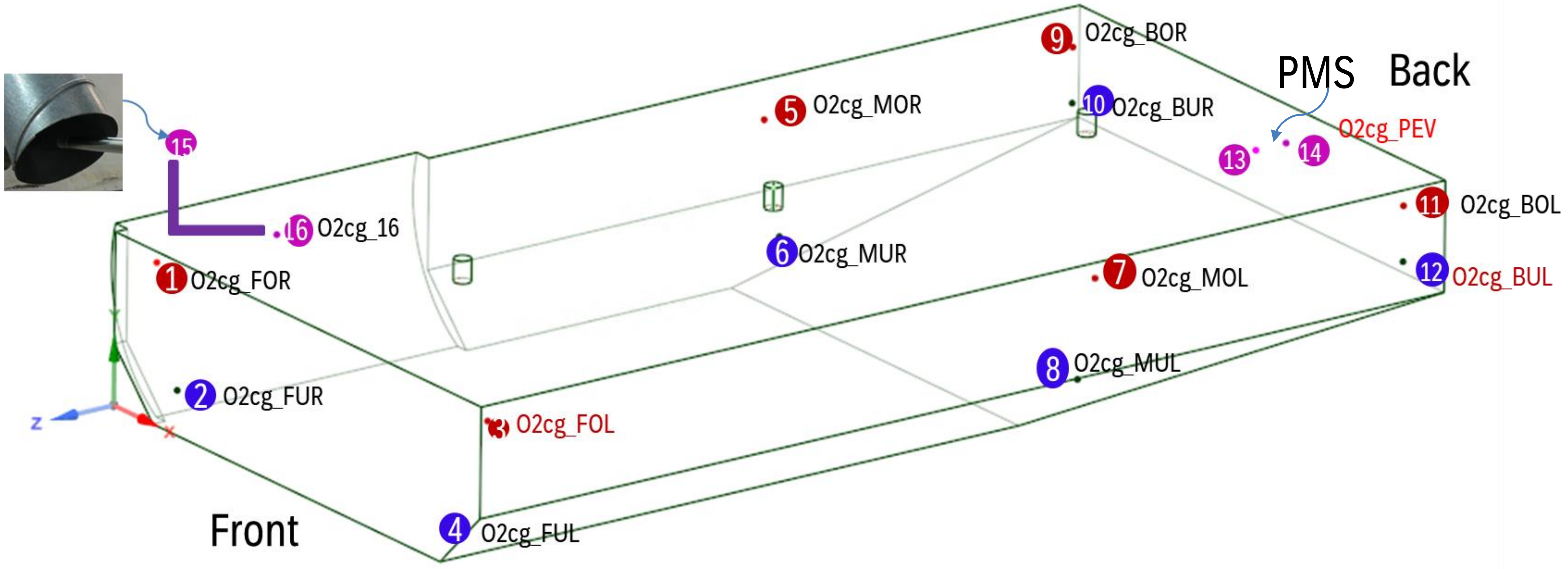


Modified SA Cargo hold

https://www.hoki.ibp.fraunhofer.de/vr/virtual-tour_IBP/#tabpanel-Virtueller%20Rundgang%20Fraunhofer%20IBP

O2 SENSOR LOCATIONS

O_2 sensor locations in cargo hold



O_2 sensors are placed at 18 locations, near ceiling and floor, near side walls in between nozzles, in leakage pipe, near pressure management system (PMS)

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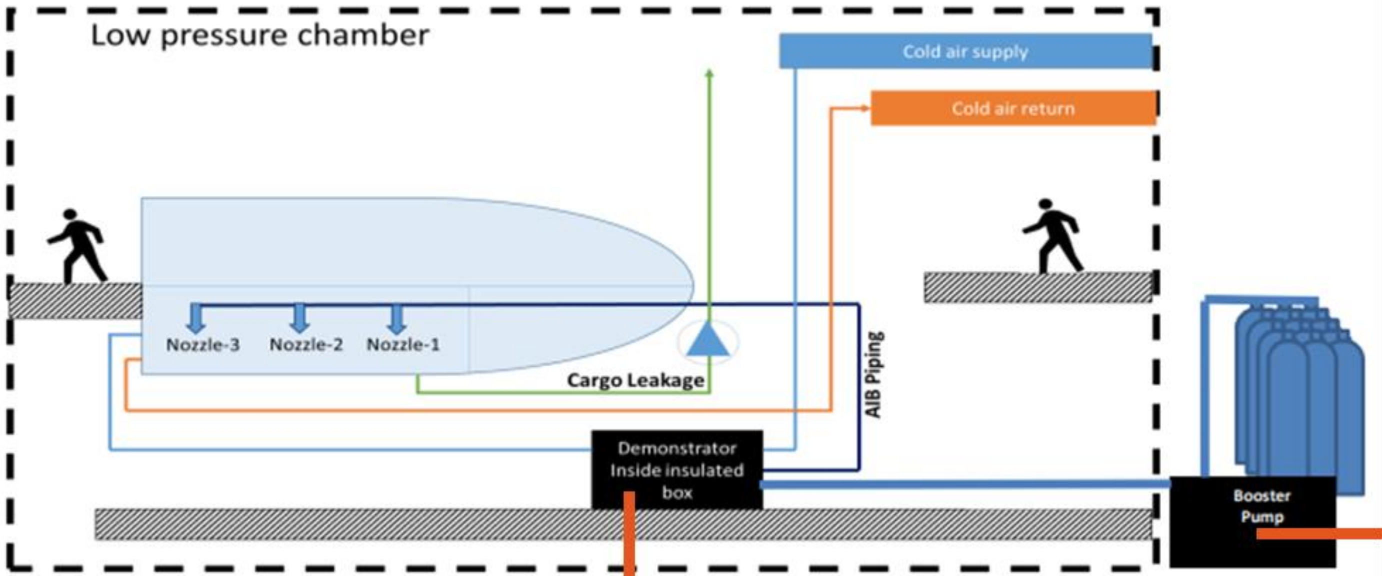
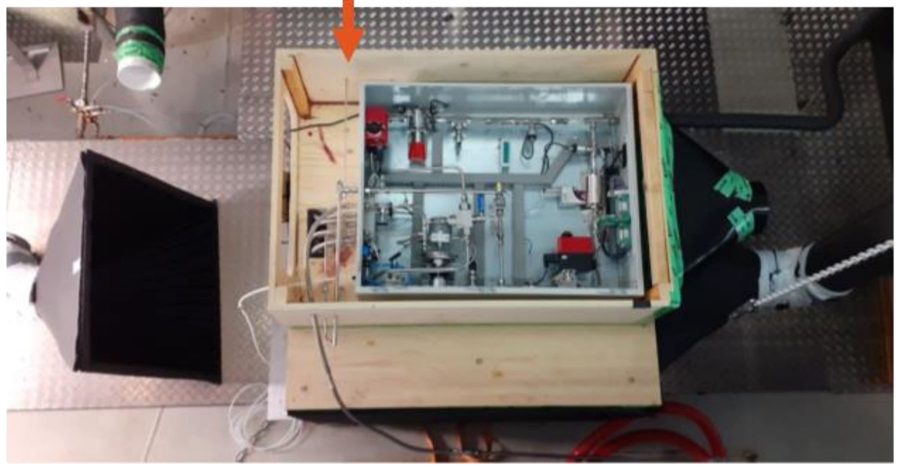
DEMONSTRATOR INSTALLATION

Demonstration installation



- Cargo Air supply
- Cargo Leakage
- Demonstrator installation
- Cylinder locations

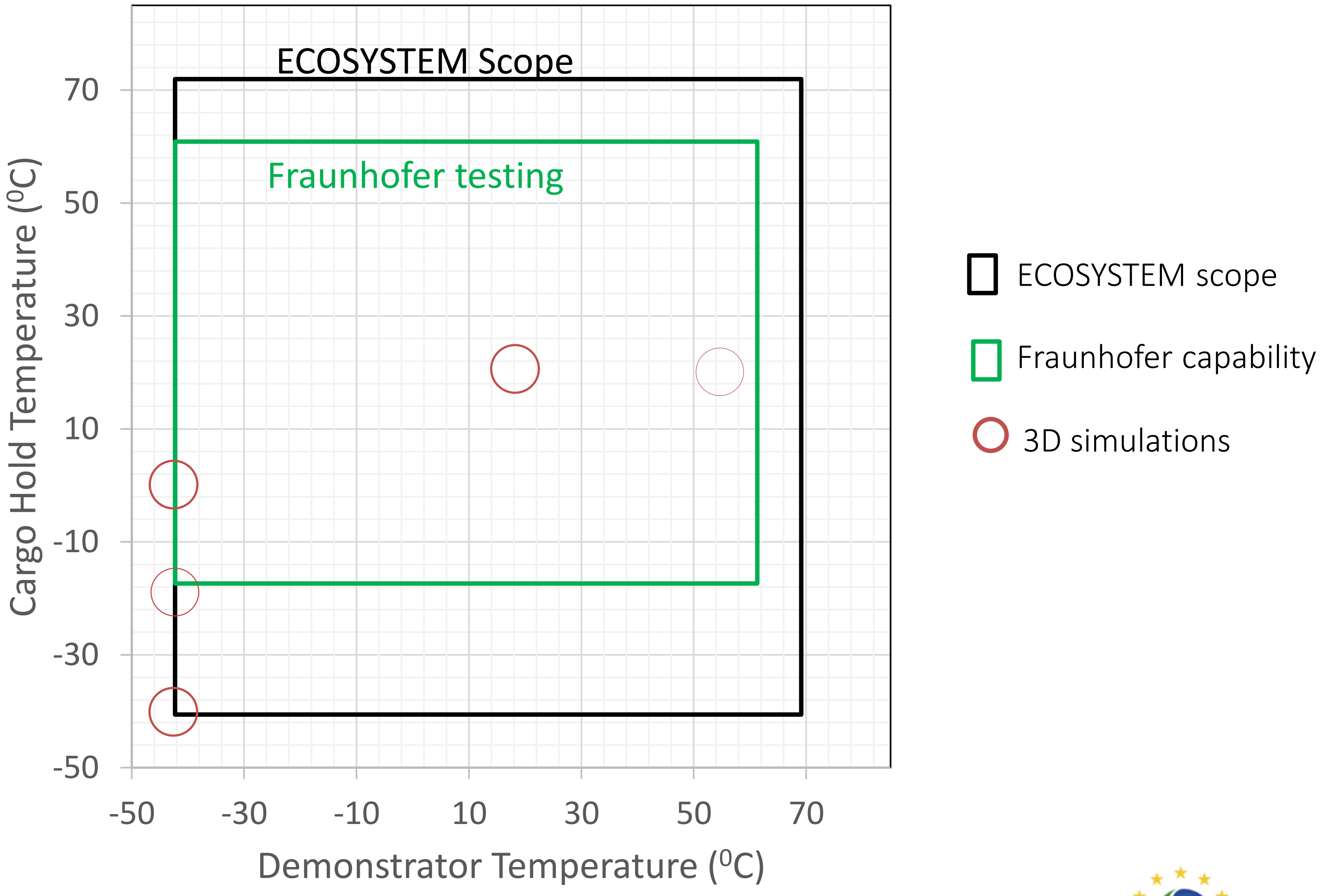
Mainfold



TESTING MATRIX

The scope of ECOSYSTEM demonstrator is to discharge Nitrogen over temperature range from -40°C to +70°C for both Demonstrator and cargo hold at ground, cruise and descent phases.

- Fraunhofer facility is capable for demonstrator temperature over range -40°C to +60°C and cargo air temperature over range-17° C to +60°C.
- 3D CFD simulations were performed for the conditions outside Fraunhofer facility test range.



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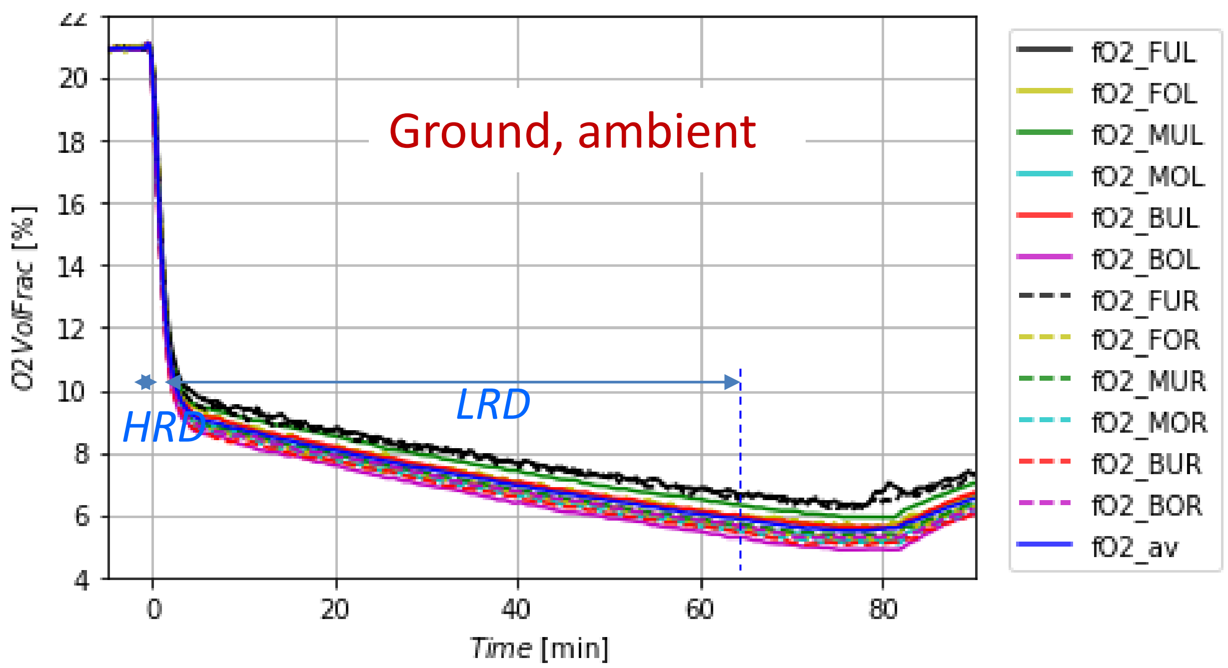
TEST MATRIX

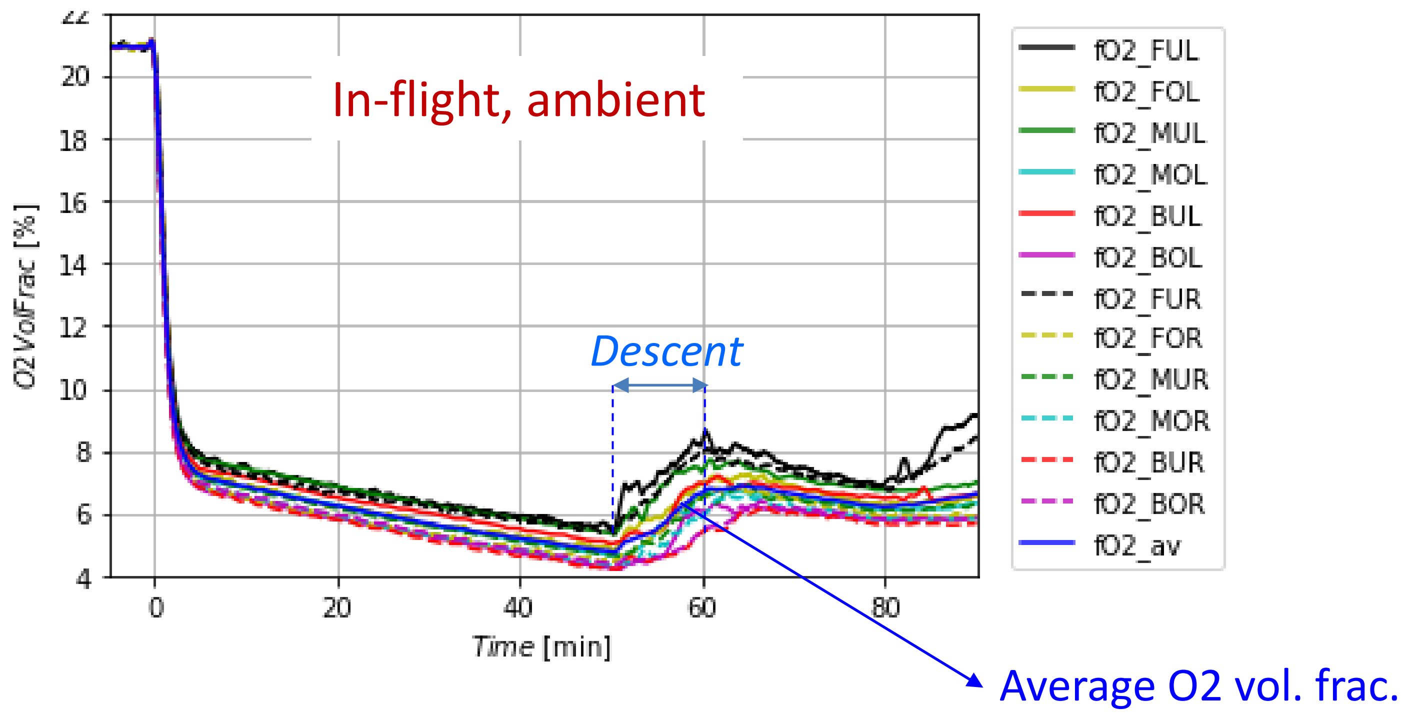
Tests covered cold, ambient and hot temperature conditions at ground and in-flight phases for empty and loaded cargos.

Test NO.	Condition	Demonstrator (°C)	Cargo Hold (°C)	Flight Phases	In flight leakage [Y/N]	Loaded factor %
1	Ground, ambient	ambient	ambient	Ground	N	0
2	In-flight, ambient	ambient	ambient	Cruise to descent 1	Y	0
3	Ground, cold	-40	-17	Ground	N	0
4	Ground, cold	-40	-17	Ground	N	0
5	In-flight, cold	-40	ambient	Cruise to descent 1	Y	0
6	In-flight, cold	-40	-15	Cruise to descent 1	Y	0
7	In-flight, cold	-40	-15	Cruise to descent 2	Y	0
8	In-flight, hot	55	ambient	Cruise to descent 1	Y	0
9	Ground, hot	55	ambient	Ground	N	0
10	Hot HRD only	55	ambient	Cruise to descent 1	N	75
11	Loaded, ambient	ambient	ambient	Cruise to descent 1	Y	75

TESTING RESULTS – EMPTY CARGO

- Tests at ground and in-flight phases





- Throughout HRD to LRD ends, O2 concentrations are lower than 9% for ground and in-flight condition.
- O2 concentration stratification showed at LRD stage because of low jet momentum from nozzles, resulting in higher O2 concentration near floor.
- For in-flight testing, O2 concentration increased during descent phase, but still maximal O2 concentration is lower than 9%. The enhanced O2 concentration stratification is caused by non-uniform leakages in cargo hold.

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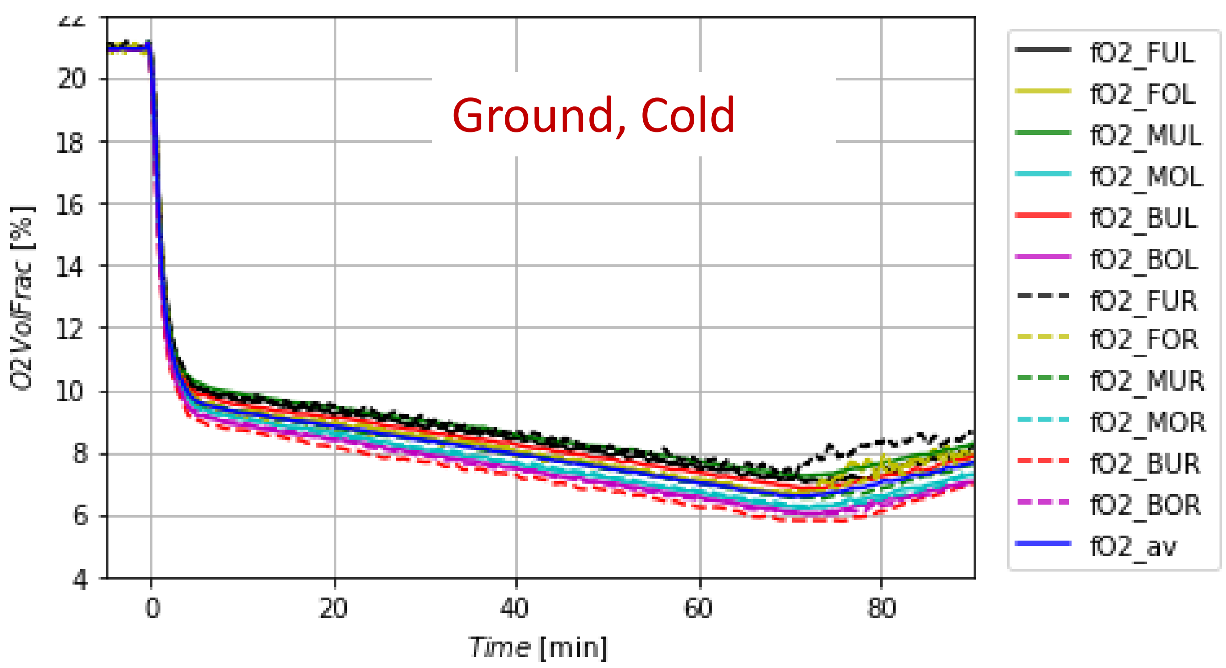
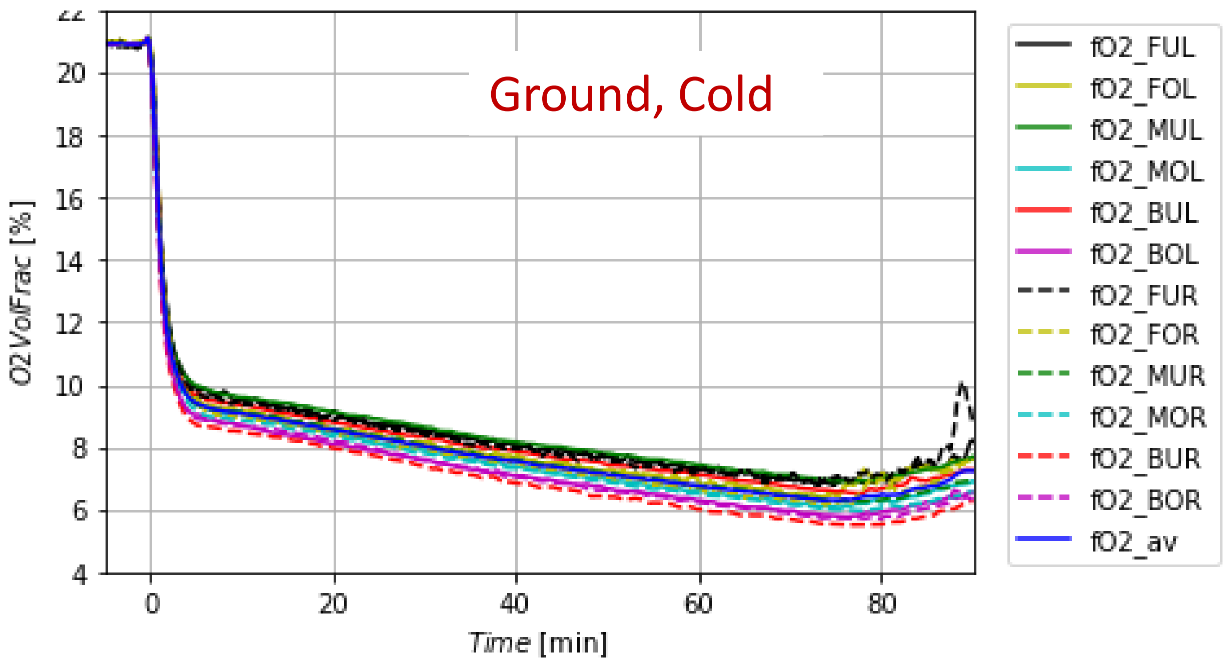
TESTING RESULTS – EMPTY CARGO

- Repeatability test:



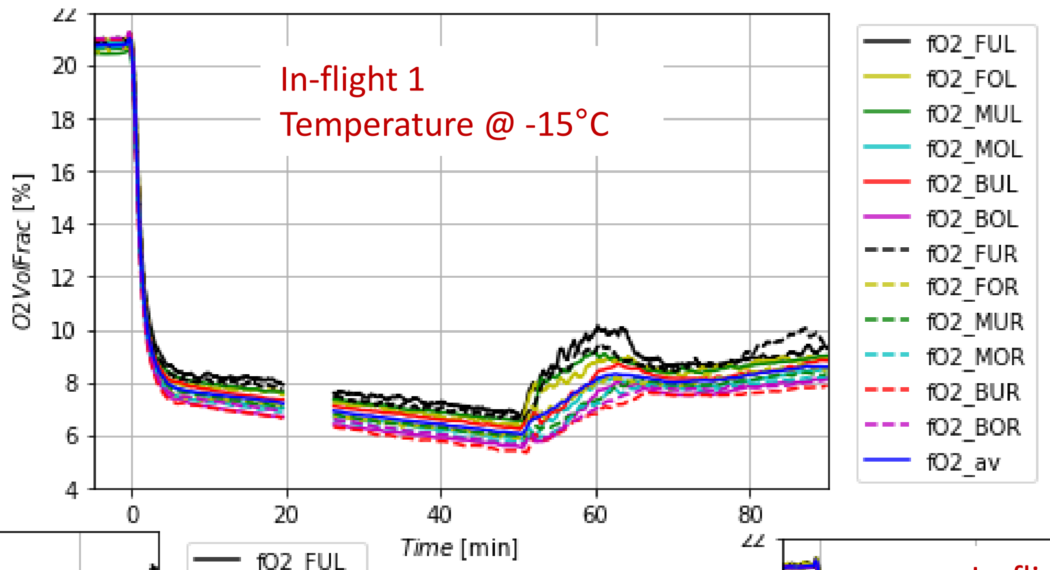


- Good repeatability of O_2 concentrations
- About 5 minutes difference of discharge time because of variation of stored Nitrogen mass in cylinders.
- Throughout HRD to LRD ends, O2 concentrations are lower than 10%, slight higher than that at ambient condition. It is worth to note that this testing condition gives highest peak O2 concentration throughout HRD to LRD ends for empty cargo.

TESTING RESULTS – EMPTY CARGO

- Cold tests: effect of increased cargo temperature and pressure

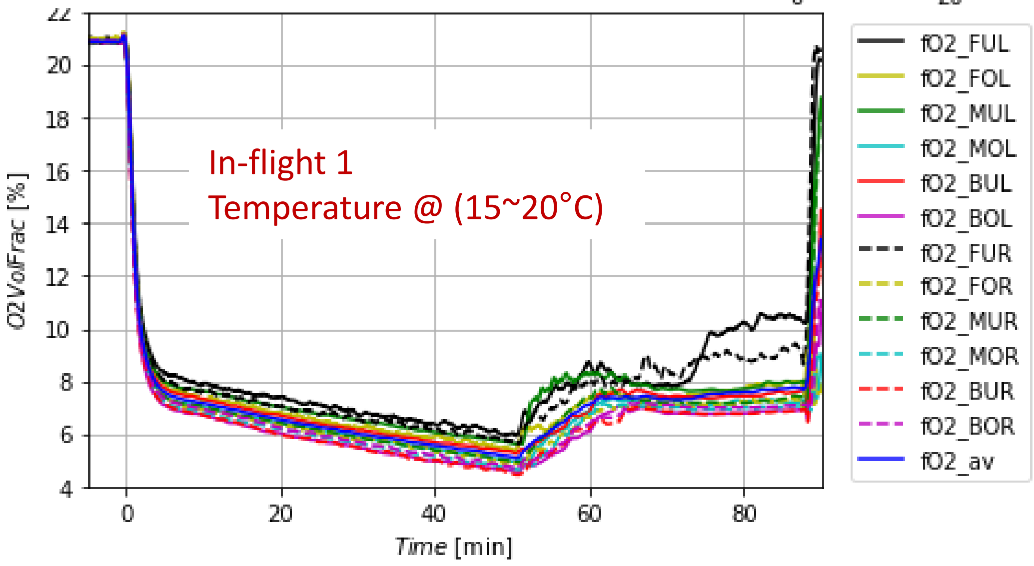
O_2 concentration decreased because of increased cargo hold temperature.

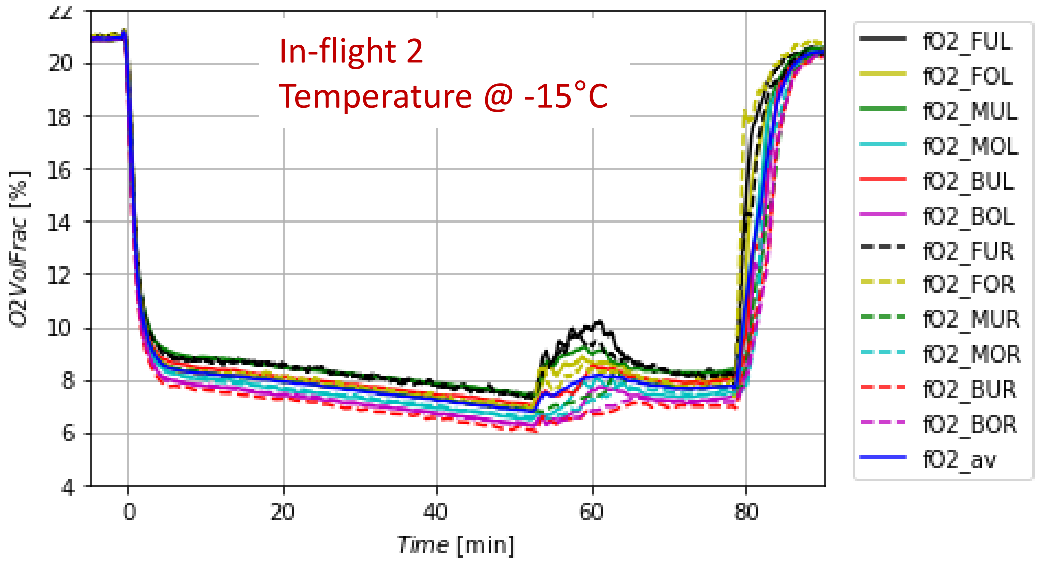


Overall O_2 concentration increased because of increased cruise pressure.

Increase cargo hold temperature.

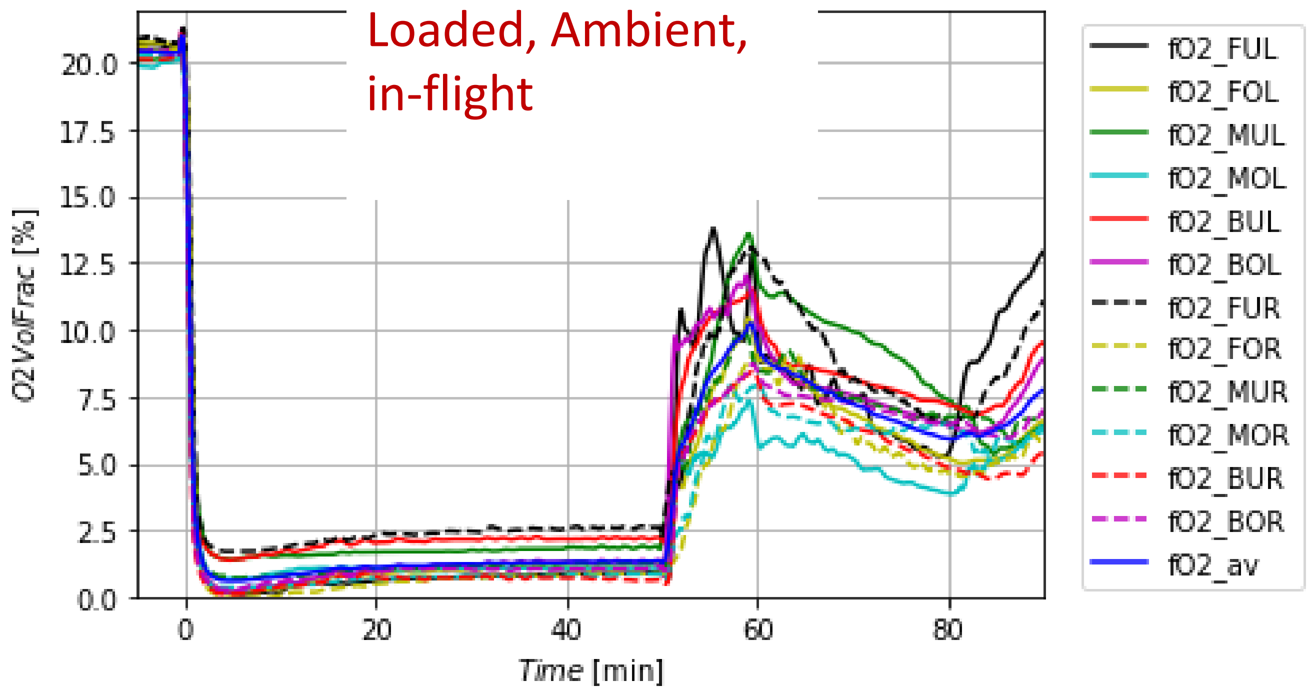
Increase cruise pressure





TESTING RESULTS – LOADED CARGO

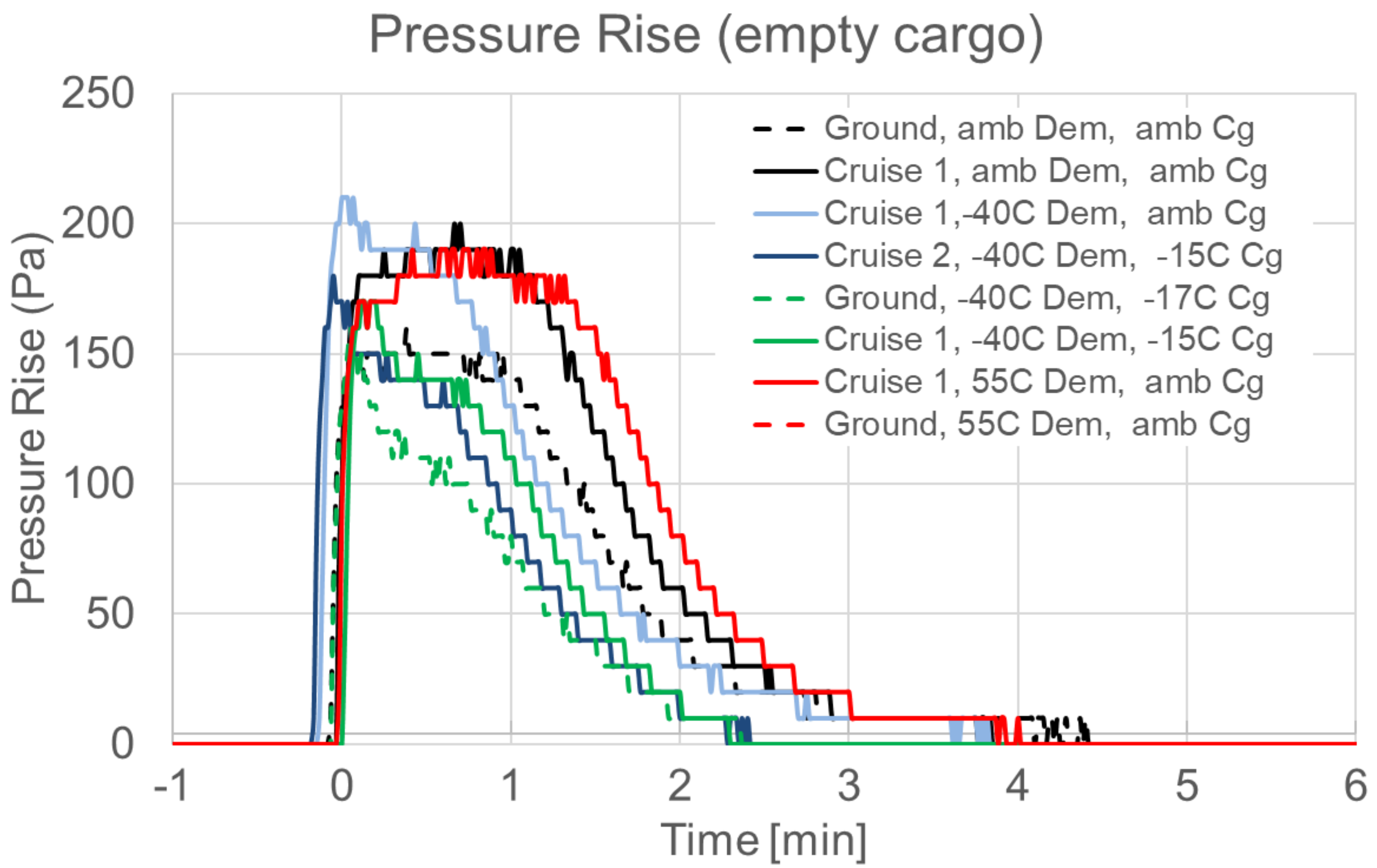
- Loaded, in-flight condition

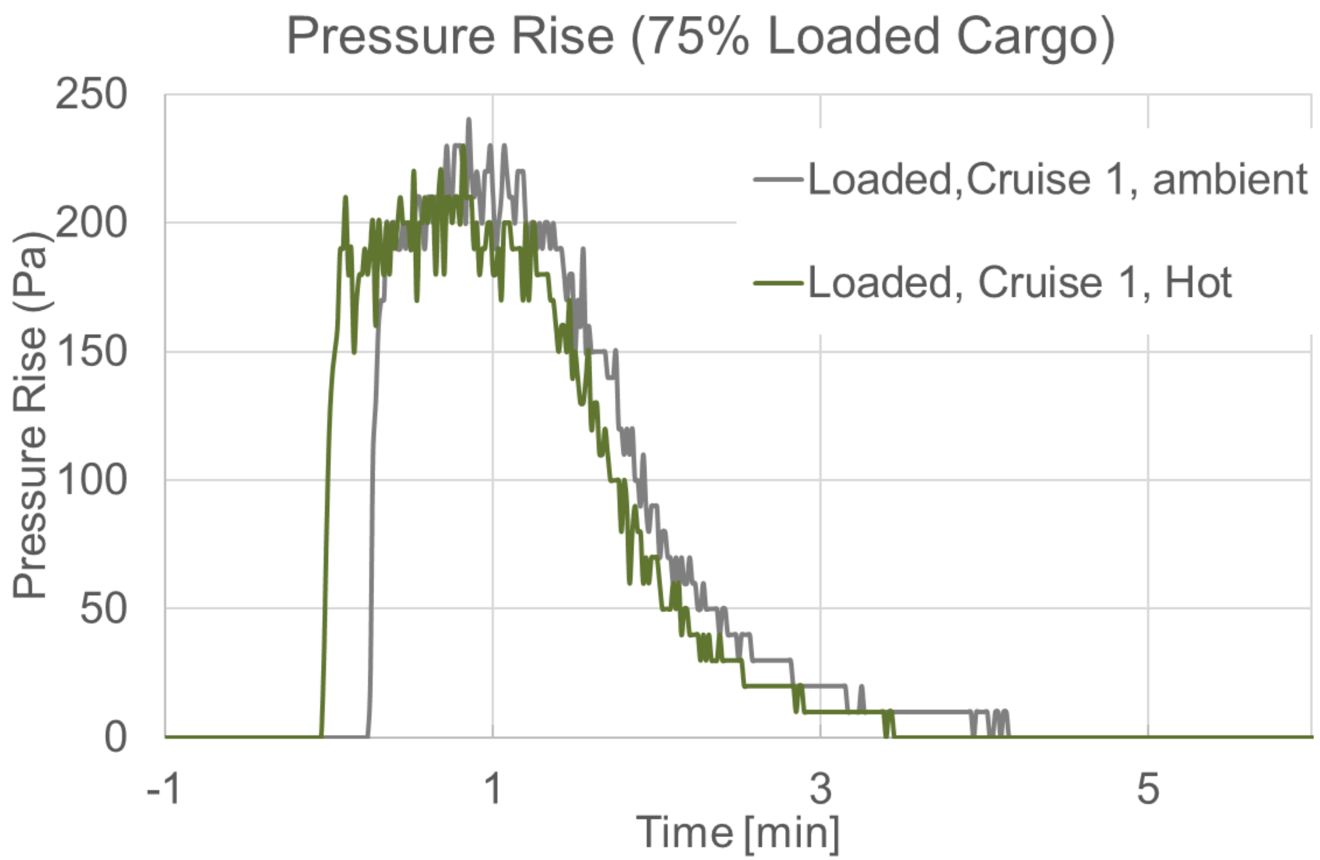


- A rapid O_2 concentration reduce showed during HRD, low concentration maintains during LRD.
- O_2 concentration increased through air ingress during decent, fluctuations showed at different locations caused by local leakage and turbulence.

PRESSURE RISE

- Pressure rise for empty and loaded cargo





- Maximum pressure rise is about 230 Pa, much lower than overpressure in the requirement because of high leakage in tests.
- Leakages (container, PMS, door, liner) shall be carefully quantified in future tests.

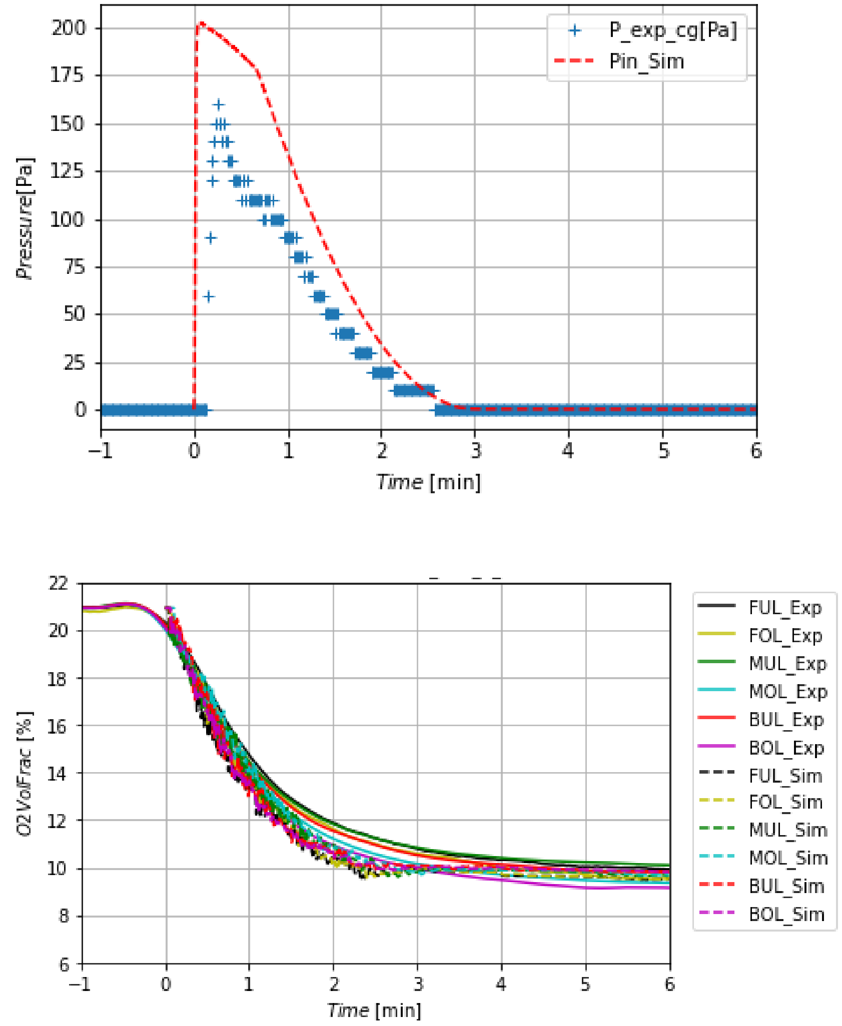
SIMULATION & TESTING COMPARISON

3D simulations performed and compared with testing results

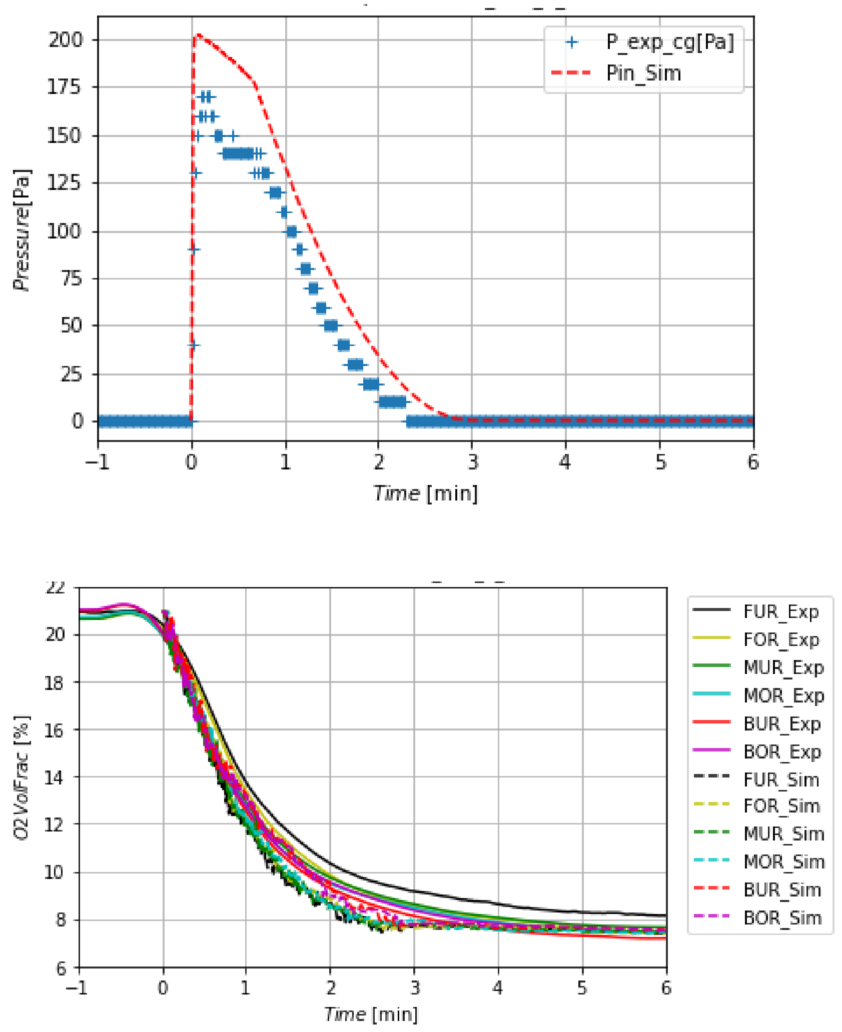
Condition	Demonstrator (° C)	Cargo Hold (° C)	Pressure (hPa)
Ground, cold	-40	-12	Ground
In-flight, cold	-40	-15	Inflight

- Good agreement showed in the comparison of the predicted and measured oxygen concentration.
- Predicted pressure is slightly higher than measured pressure, but overall trends are well captured.
- The disparity of pressure can be reduced by adjusting the fitting curve of leakage rate, however, this improvement on O_2 concentration is insignificant.

Ground



Inflight



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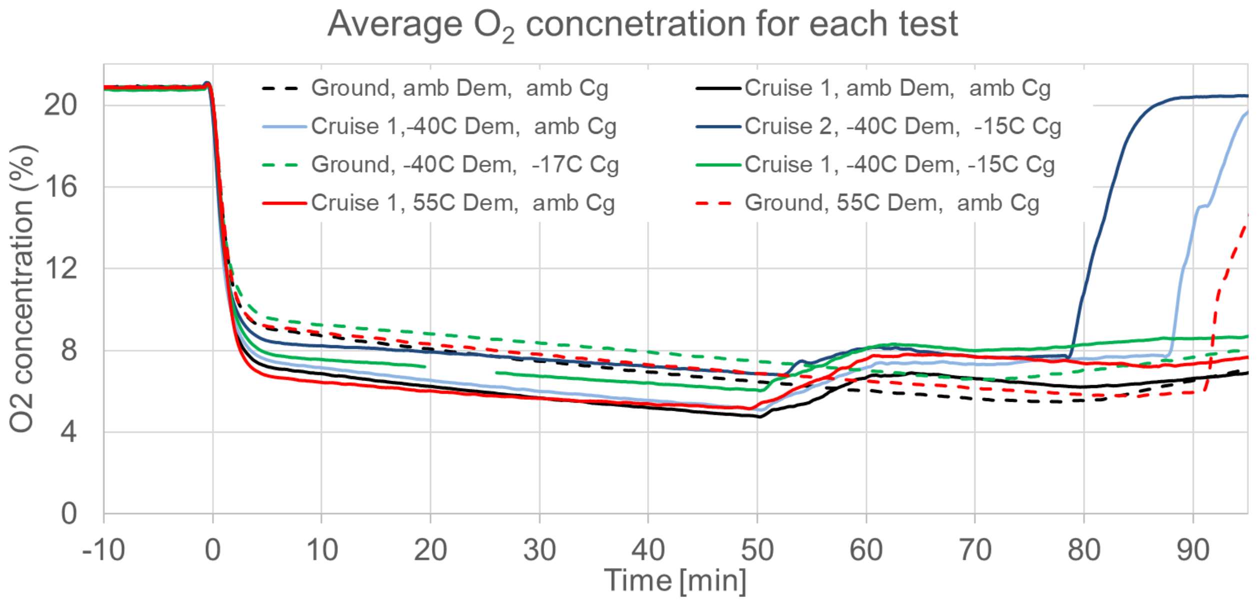
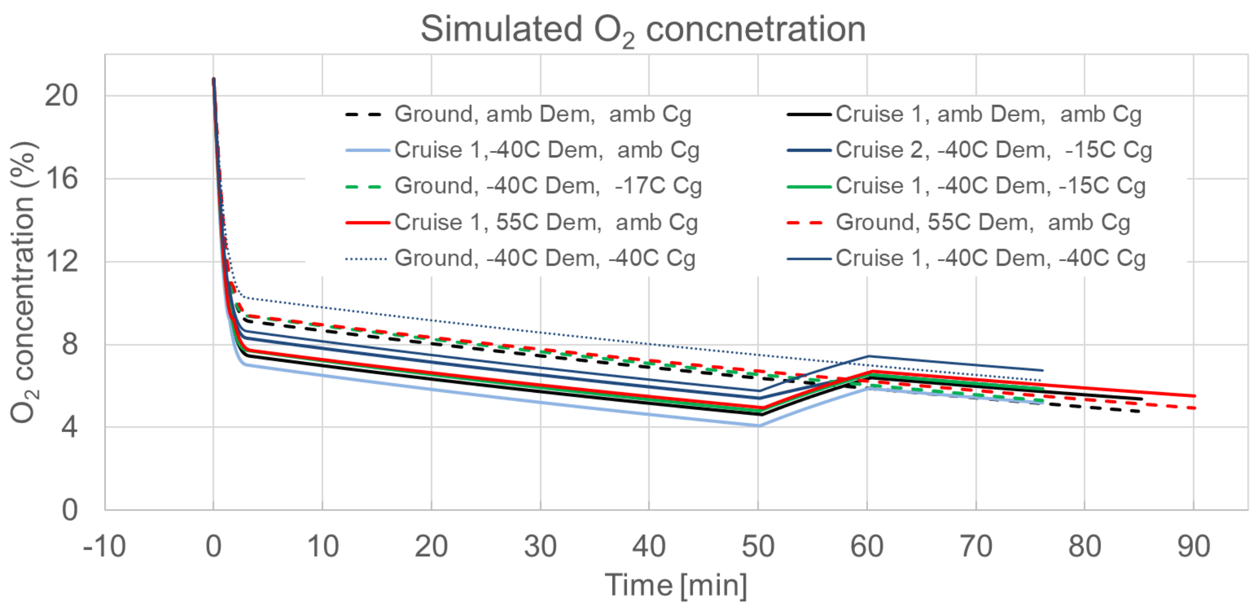
SIMULATION & TESTING COMPARISON

Comparison oxygen concentration results of 0D simulations with testing

Averaged oxygen concentration from testing



Predicted oxygen concentration using 0D code



- Solid lines are the results of tests at in-flight condition, dash lines are the results of tests at ground condition. Results for hot, ambient and cold conditions are in red, black and green/blue, respectively.
- Compared to averaged oxygen concentration from testing, overall trends are well captured in the 0D modelling.

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SUMMARY

- Demonstrator has been designed, built and tested as ground and simulated in-flight conditions.
- A successful testing campaign was conducted at Fraunhofer Institute, Holzkirchen, Germany by achieving the required oxygen concentration
- Demonstrator discharge tests were completed at different conditions including ambient, cold and hot temperature conditions, ground and in-flight conditions as well as empty and loaded cargo configurations.
- The CFD predictions and 0D modelling results were compared with the measured data and good agreement was obtained in terms of oxygen concentration data

ACKNOWLEDGEMENTS

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- Airbus as Topic Manager
  - *Rainer Beuermann, Nadine Gomm, Andre Freiling*
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  - *Arnav Pathak, Marie Pschirer, Victor Norrefeldt, Max Kienberger*
- Collins Aerospace Team
  - *El Hassan Ridouane, Laurie O'Sullivan, Hitesh Mistry, Francois Petetin, Francois Breton, Morgan Carrier, Detlev Degenhardt, Carlos Manglano, Gerrit Krause, Jens Krissun, Weronika Batog, Lukasz Turek*
- FAA Tech Center

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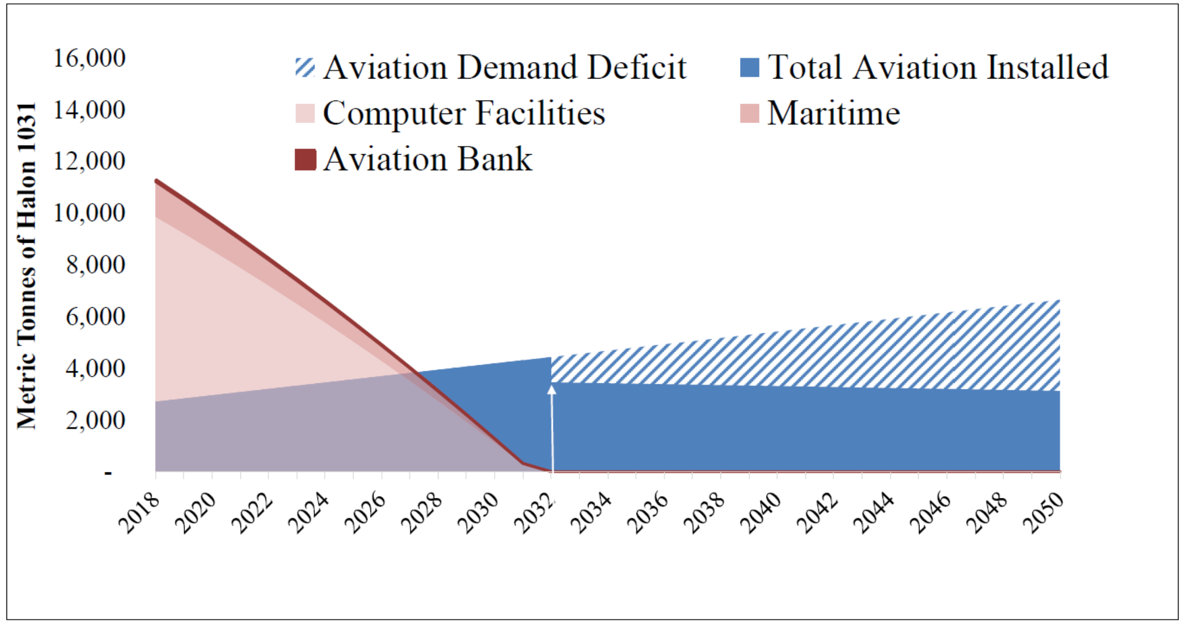
BACKUP

EXPECTED IMPACT

Project expected impact:

- Regulation (EC) No 1005/2009 of the European Parliament on substances that deplete the ozone layer
- Elimination of a highly ozone-depleting and global warming substance
- Replace halon by nitrogen, a sustainable alternative to an ozone-depleting and global warming gas
- Successfully use inert gas in aerospace
- Having this technology at **TRL 5 is a step further to** bringing a **product to market**
- Strengthen European aerospace industry competitiveness



Halon 1301 availability

[Oct18Meeting/Verdonik-1018-XXIX-8.pdf]

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