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Parametric Study of Avionic Rack Ventilation System

Project Team—Aybike Bezcigil, Harita Satpute, Hiren Parmar, Mehmet Onur Özgüner, Simran Hakim, Sonal Bhaskar

Airbus Supervisors—Jens Lohmar and Felix Braun

INTRODUCTION

What are avionic racks?

- The term "avionics" is derived from aviation + electronics. It refers to the electronic systems that support an aircraft's flight and mission functions.
- An **avionics rack** is a structural framework that securely holds the avionic systems.
- It also provides cooling and power to these systems. The cooling is achieved by passing cool air through the electronics.

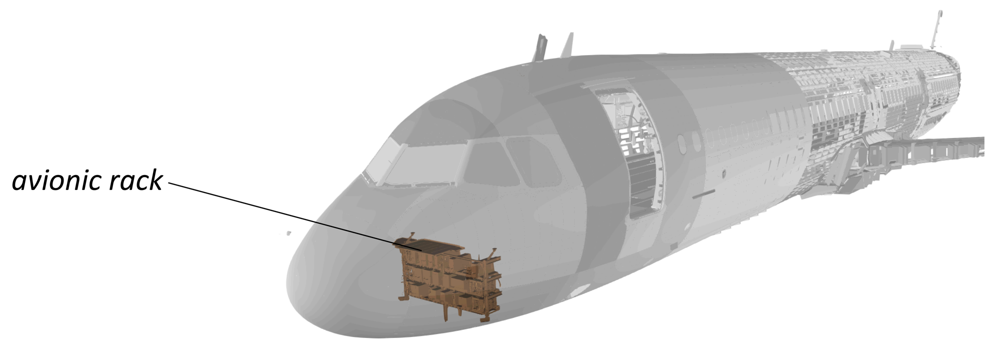

Figure 1: *Depiction of an avionic rack (90VU) placed in the avionics bay of a single isle aircraft.*

PROBLEM STATEMENT

- The cooling air is drawn from the engine compressor, which comes at the cost of reduced engine performance. Hence, it is a valuable commodity.
- The growing electrification of modern aircraft requires more efficient utilization of cooling air.
- In the avionic rack, cooling air passes through the avionics via blowing channels and is collected by an extraction fan. The close proximity of blowing and extraction channels leads to heat interaction, reducing cooling effectiveness and increasing coolant usage.
- An analytical model of the rack's pneumatic and thermal behavior is needed to determine a geometry that optimizes cooling performance and resource efficiency.

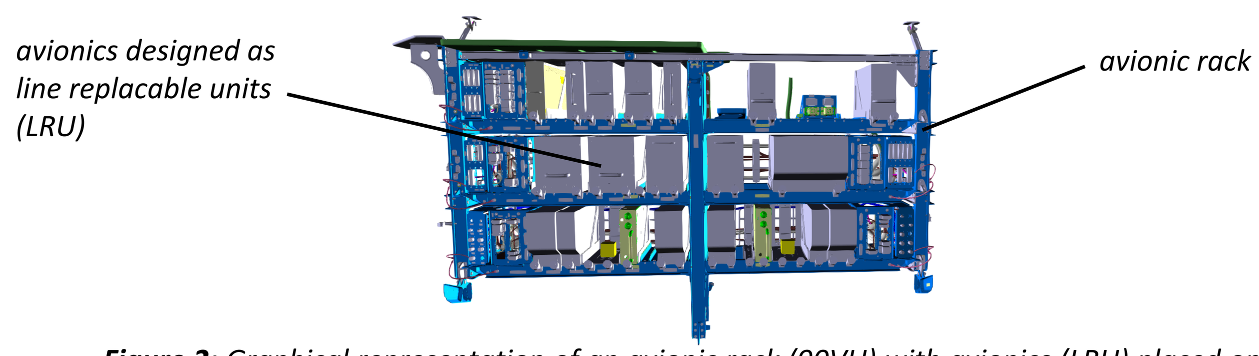

Figure 2: *Graphical representation of an avionic rack (90VU) with avionics (LRU) placed on its shelves.*

METHODOLOGY

The rack was divided into zones, and the pneumatic and heat transfer characteristics of each zone were calculated before being aggregated to obtain the overall behavior.

Fluid Flow Problem

The different pressure losses in the flow path were identified and calculated using respective formulas. The losses are:

- Losses due to friction in the flow channel.
- Flow distribution losses.
- Losses due to the presence of holes (air outlets to the LRU).

Heat Transfer Problem

Heat transfer occurs via forced convection from the supplied coolant on all rack walls in contact. On the other sides of the rack wall, different modes of heat transfer are:

- Forced convection with the extraction coolant.
- Natural convection with the ambient air.
- Isothermal surface approximation.

The equations for these heat transfer modes were incorporated into the corresponding thermal resistance circuits to determine the overall heat interaction.

SOLUTION STRATEGY

System Inputs

- Number of MCUs
- Heat Dissipiation
- Ambient Temperature
- Coolant Inlet Temperature
- Dimensions of the Rack
- Coolant Airflow Rate

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Solution Process

- Heat Transfer Calculations
- Python Code
- Fluid Flow Calculations

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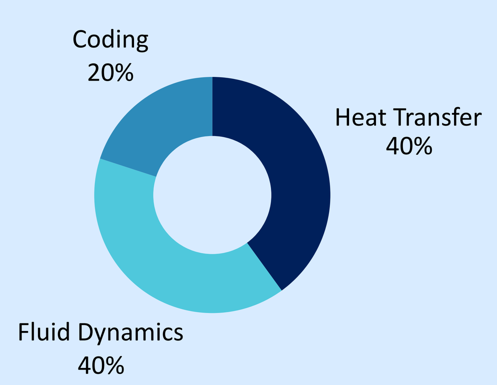
Optimization Outputs

- Airflow Pressure
- Coolant Velocity
- Coolant Temperature

Solution Composition



RESULTS: HEAT TRANSFER

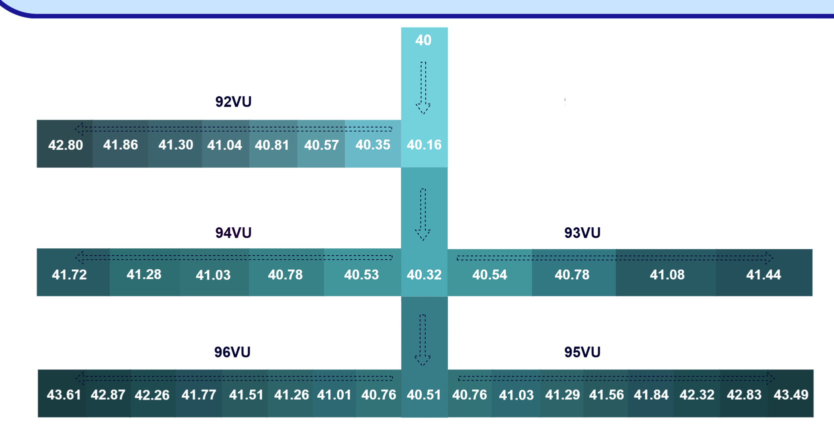


Figure 3: *Depiction of the coolant temperatures (°C) in different zones on the blowing side of a 90VU avionic rack.*

- The highest temperatures occur in the last zones of the final shelves. This happens because the coolant, as it travels farther through the channels, is exposed to unwanted heat sources for a longer duration.

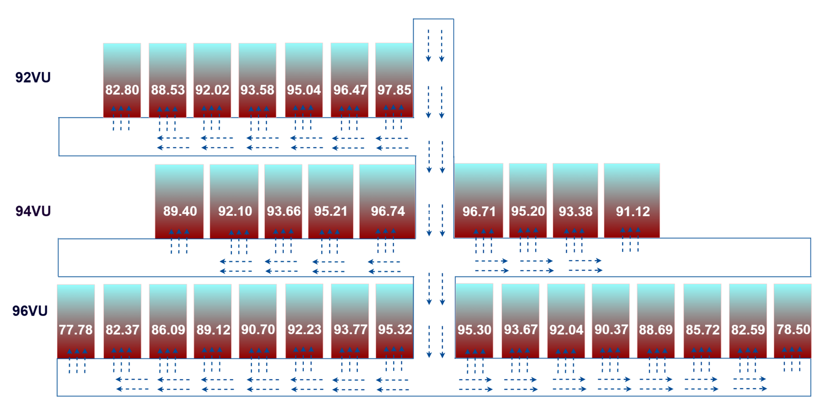


Figure 4: *Depiction of the cooling efficiency in % for different zones of a 90VU avionic rack.*

- As a result, the coolant reaches the LRUs at temperatures above the recommended limits, reducing the efficiency of avionic cooling. This behavior follows the same trend as the temperature distribution.

RESULTS: FLUID FLOW

Volume Flow Rate as a Parameter

- The highest pressure losses are observed in 93VU and 94VU, primarily due to elevated loss coefficient values associated with the branches in a cross-flow distribution.
- The exponential increase in pressure losses arises from their proportionality to the square of the volume flow rate.

$$\Delta P = \rho/2 \cdot K_{loss} \cdot (\dot{V} / A)^2$$

where:
ΔP = Pressure losses
ρ = Density
K_{loss} = Loss coefficient
$\dot{V}$ = Volume flow rate
A = cross-sectional area

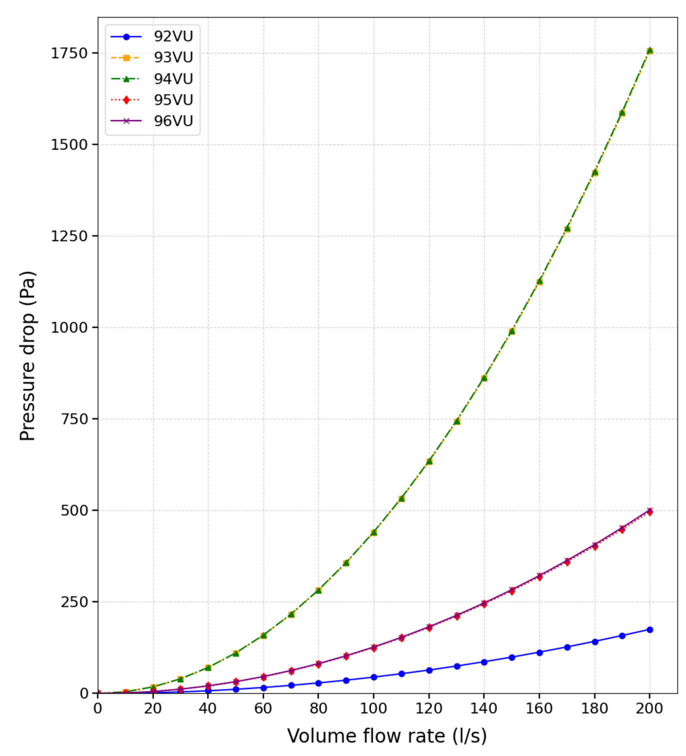


Figure 5: *Graph of the maximum pressure loss (Pa) in each shelf versus the overall volume flow rate (l/s) of the coolant in a 90VU avionic rack.*

CONCLUSION

- Since the results indicate reduced heat transfer efficiency near the shelf ends, where coolant temperatures are highest, the most critical LRUs should be placed higher and also closer to the vertical channels.
- The high pressure losses in 93VU and 94VU highlight the importance of minimizing branch loss coefficients in cross-flow regions to improve overall cooling efficiency.

INDIVIDUAL WORK OVERVIEW		
Aybike B.	Fluid Flow Model	90h
Harita S.	Product Owner and Heat Transfer	90h
Hiren P.	Fluid Flow Model	90h
M. Onur Ö.	Fluid Flow Model	90h
Simran H.	Scrum Master and Fluid Flow	90h
Sonal B.	Heat Transfer and Fluid Flow Model	90h

For more results..

SCAN ME