



# Data-Driven Complex System Modeling

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**LIEBHERR**

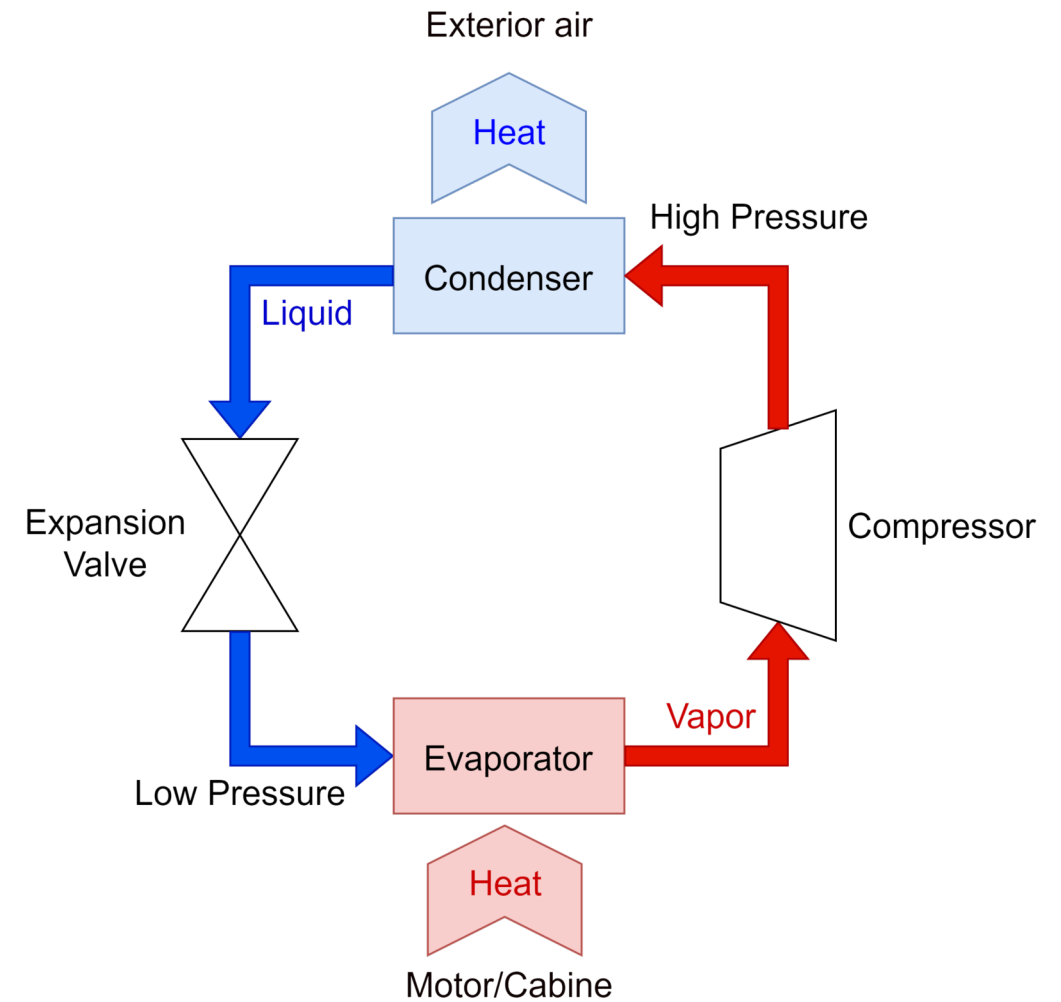


## Air Conditioning in Aircraft



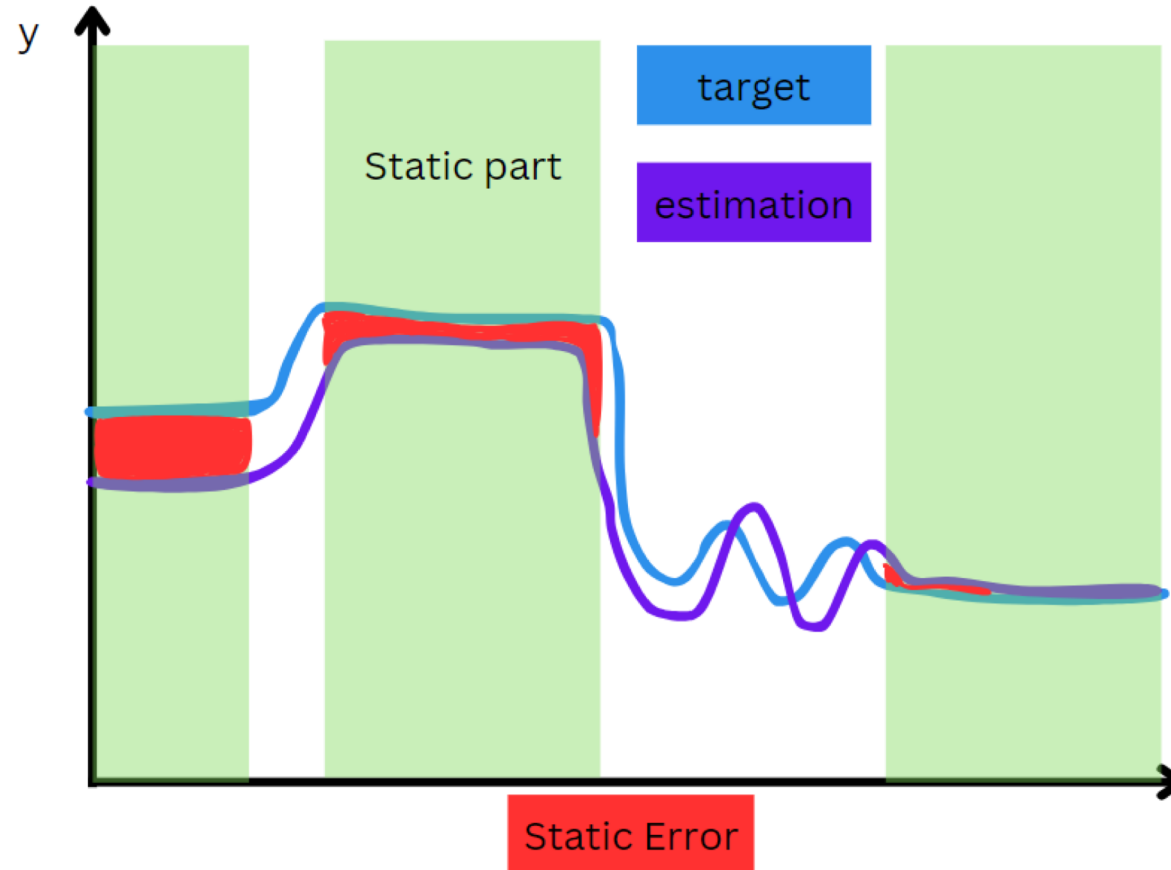
**Control the air conditioning system requires having a mass flow sensor with sufficient:**

- **Static precision**
- **Dynamic accuracy**

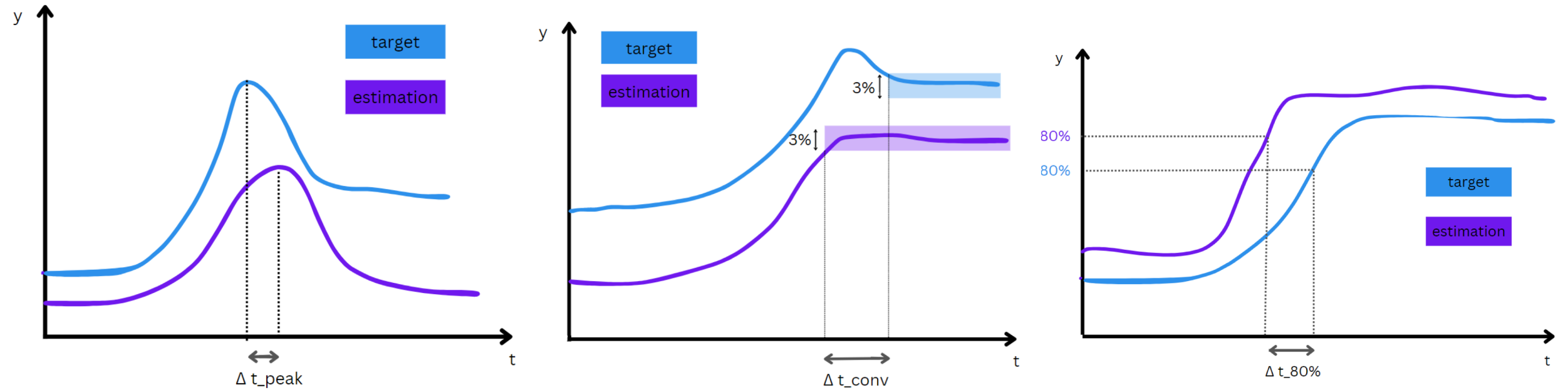


# Static Specification

## 2 static performance metrics: Absolute and Relative errors



## 3 dynamic performance metrics



## There are no embeddable physical flow sensors for aircraft

In the LIEBHERR's Laboratory, a **physical flow sensor** was used to create a dataset.

Embeddable sensors					Not Embeddable sensor
Time	Pressure	Temperature	Motor Speed	...	Mass Flow
0	$P_0$	$T_0$	$\omega_0$	...	$\dot{m}_0$
1	$P_1$	$T_1$	$\omega_1$	...	$\dot{m}_1$
2	$P_2$	$T_2$	$\omega_2$	...	$\dot{m}_2$
...	...	...	...	...	...
T	$P_T$	$T_T$	$\omega_T$	...	$\dot{m}_T$

**Two statistical models are trained and tested to estimate the flow:**

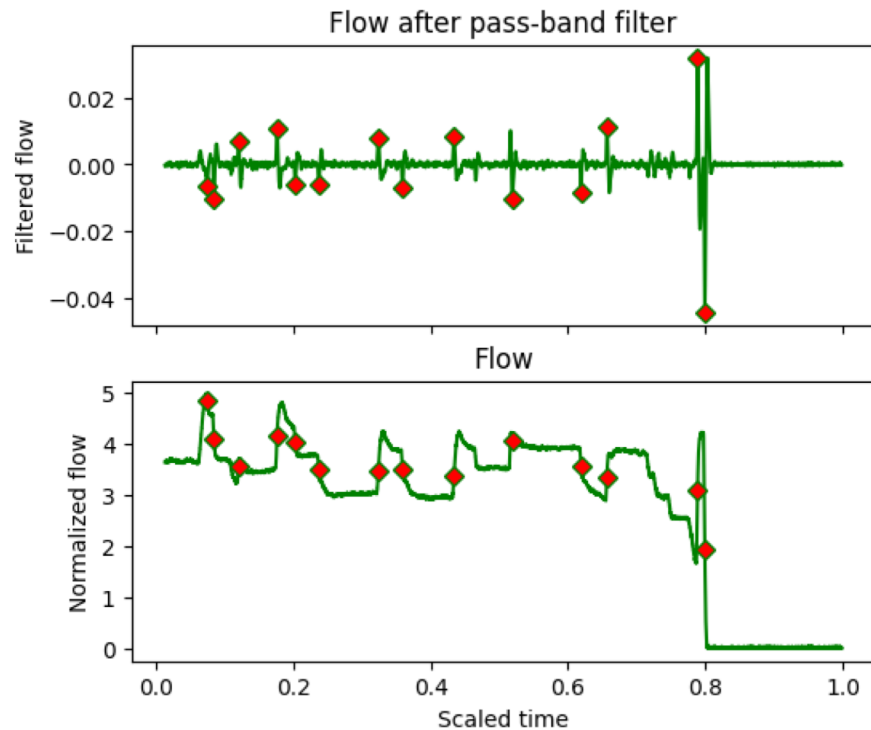
- **Polynomial Regression (PR)**
- **Convolutional Neural Network (CNN)**

# Evaluation with performance metrics

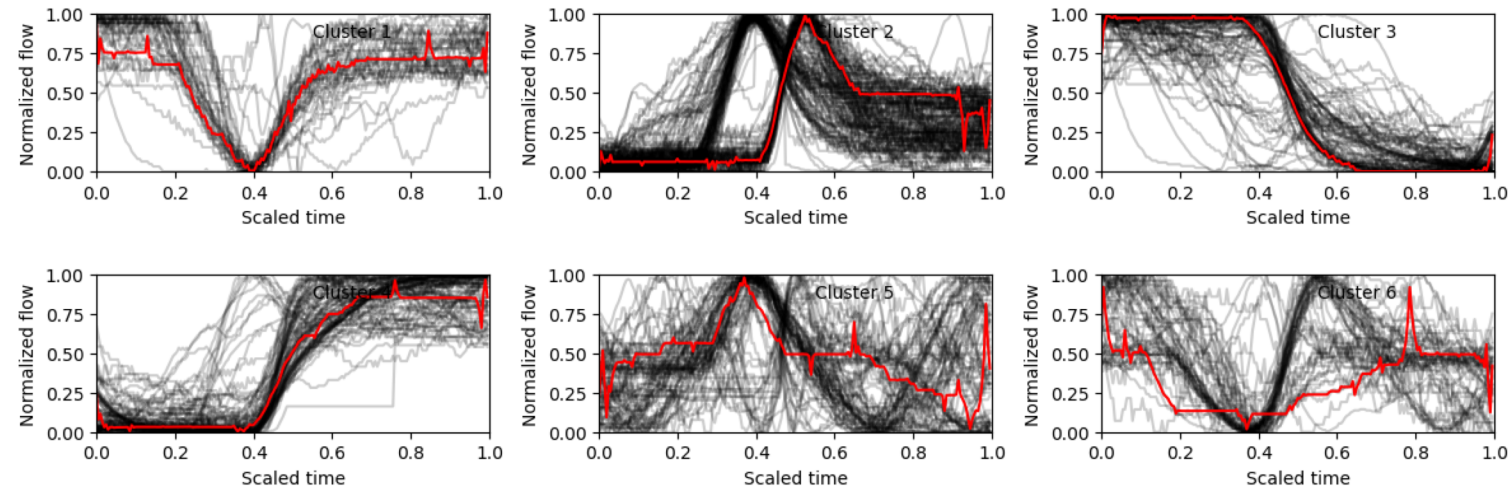
**Aiming to have a robust evaluation, multiple performance metrics are computed**

It requires a segmentation step : Static parts, Peaks and Ramps

**First, a frequential criteria is used to identify potential peaks and ramps**



**Then, a Clustering based on Dynamic Time warping is applied**



The CNN achieves better performances in terms of

- Mean Squared Error (MSE)
- Static Performance metrics
- Dynamic Performance metrics

	PR		CNN	
	train	test	train	test
MSE	0.2	0.18	<b>0.063</b>	<b>0.06</b>
$E_{abs}$	0.53	0.73	<b>0.19</b>	<b>0.28</b>
$E_{rel}$	21%	28%	<b>11%</b>	<b>14%</b>
$\Delta t_{80\%}$	65	20	<b>33</b>	<b>17</b>
$\Delta t_{10\%}$	92	<b>3</b>	<b>17</b>	3.6
$\Delta t_{conv}$	97	44	<b>74</b>	<b>14</b>
$\Delta t_{peak}$	<b>9</b>	7.1	11	<b>7</b>

Table: Comparaison on MSE and 90% quantile



# Thank you for your attention