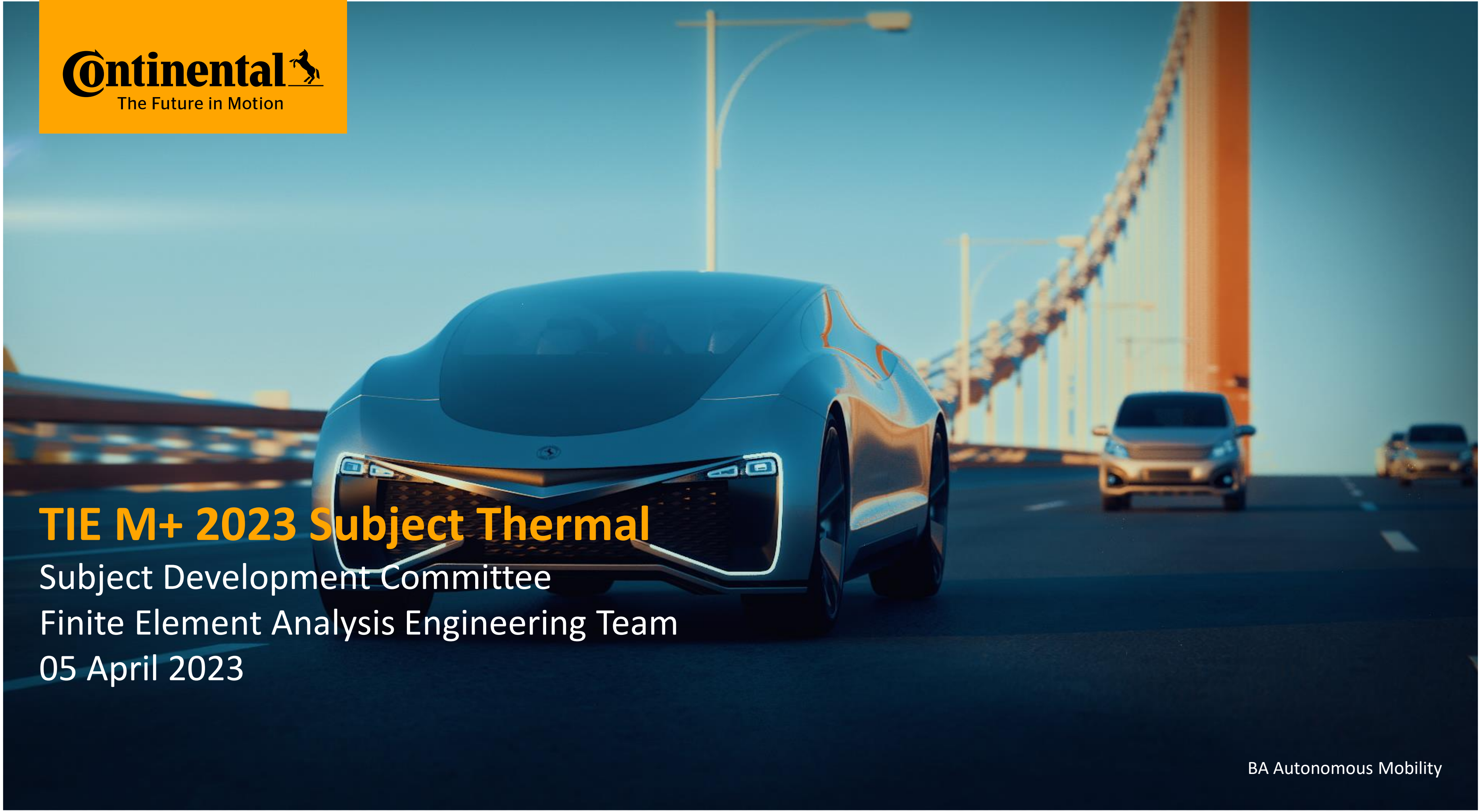


TIE M+ 2023 Subject Thermal

Subject Development Committee
Finite Element Analysis Engineering Team
05 April 2023

BA Autonomous Mobility

TIE M+ 2023 Subject

Introduction

- **Task description:**
  - The calculation of the equivalent thermal conductivity of the PCB.
  - Determining the junction temperatures on each electronic component.
  - Calculation of the thermal resistance of the sensor.
- **Scope:** To determine which electronic components are critical and to evaluate which design solution is more beneficial.
- **Requestor:** TIE M+ Organizing Committee
- **Inputs:**
  - CAD: TIE-M_Plus_CAD_Thermal.stp → will be released on April 10th
  - All the information about the materials can be found in the presentation

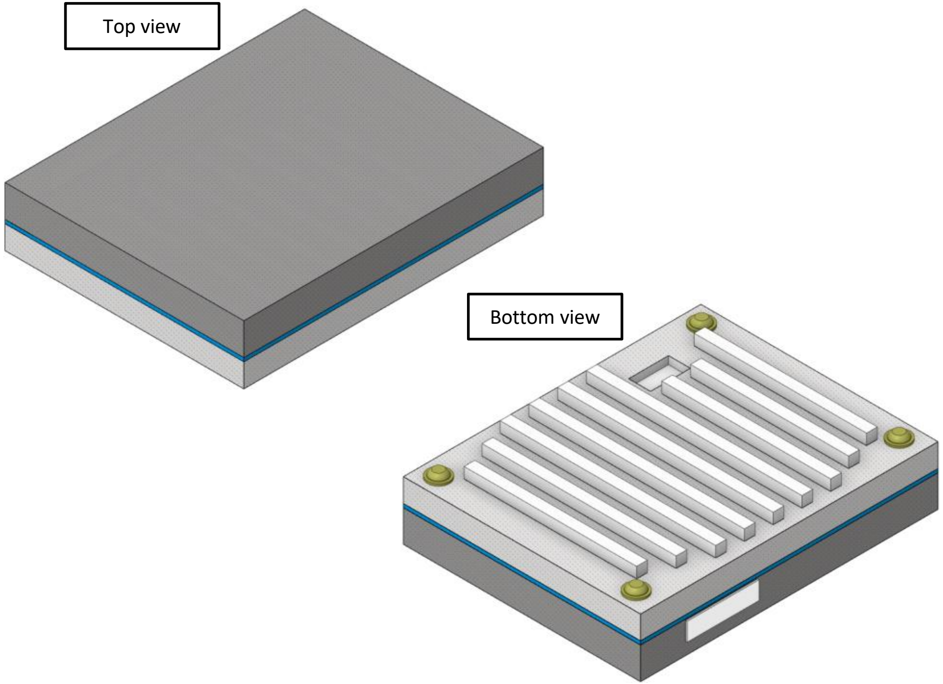
TIE M+ 2023 Subject

Introduction

- As a simulation engineer you are required to perform the analysis according to the task requirement in the previous slide and given inputs.
- You must provide a presentation report respecting the given template (DEMO presentation can be used).
- Mechanical designers usually have follow-up questions to better understand their design and where they should make improvements. Briefly answer the questions on the last slide. If you need to, you can run extra simulations scenarios to answer the questions, however, you don't need to document them.
- For extra points, answer the theory questions as well.

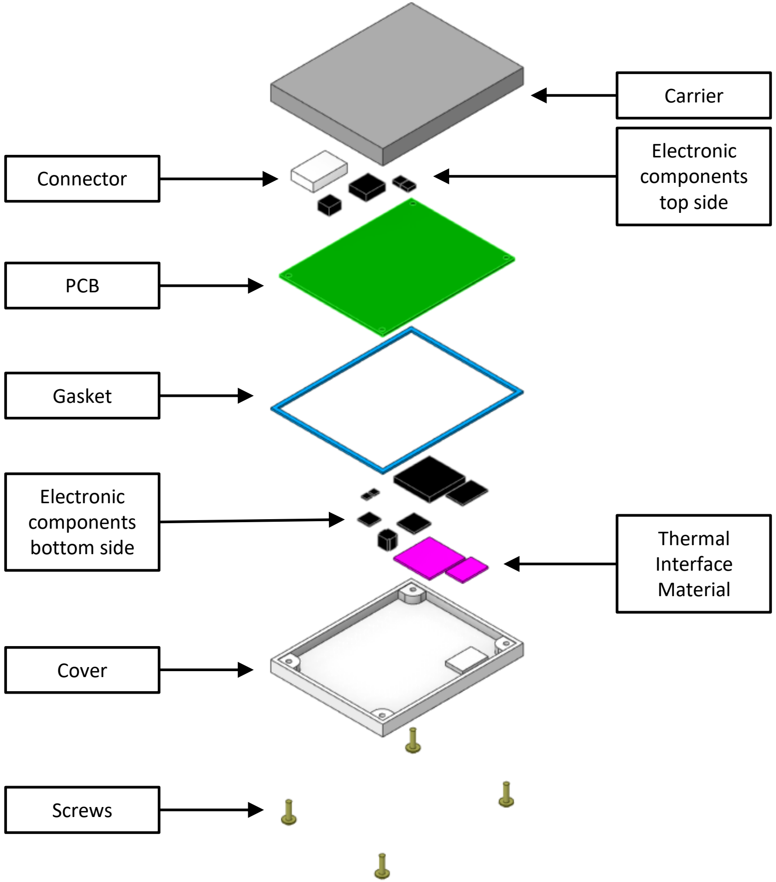
TIE M+ 2023 Subject

Assembly Description



Top view

Bottom view



Carrier

Connector

Electronic components top side

PCB

Gasket

Electronic components bottom side

Thermal Interface Material

Cover

Screws

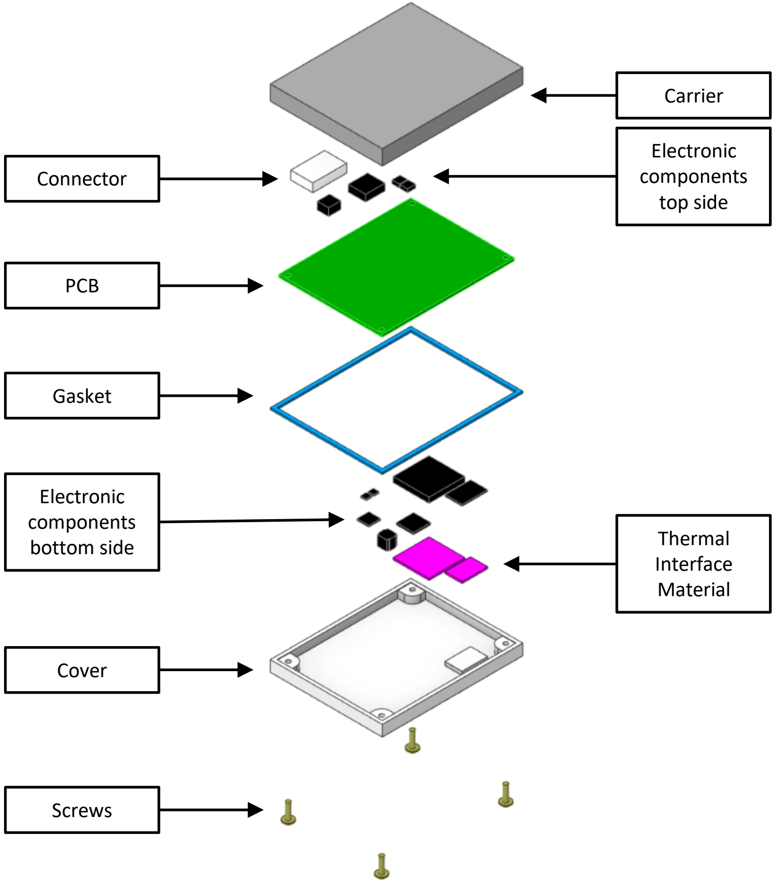
Continental Ansys ALTAIR APTE UPSEE

UP-SKILL ENGINEERING EDUCATION

TIE M+ 2023 Subject

Material proprieties

		Physical properties			Radiation properties	
Part Name	Material name	Thermal conductivity [W/mK]	Specific heat [J/kgK]	Density [kg/m^3]		Emissivity [-]
Carrier	Al Die Cast	203	879	2700	Al commercial	0.09
					Al anodized	0.8
Connector	Polycarbonate	0.23	1050	1200	Black	0.9
PCB	FR - 4	must be calculated	795	1900	Shellac brigt	0.82
Gasket	Loctite QMI536NB	0.3	1500	1400	Black	0.9
TIM	BQ GF-4000	4	800	3100	Blue	0.5
Cover	Al Die Cast	203	879	2700	Al commercial	0.09
					Al anodized	0.8
Screws	Steel stainless	23.4	431	7750	Steel stainless	0.23



Carrier

Connector

Electronic components top side

PCB

Gasket

Electronic components bottom side

Thermal Interface Material

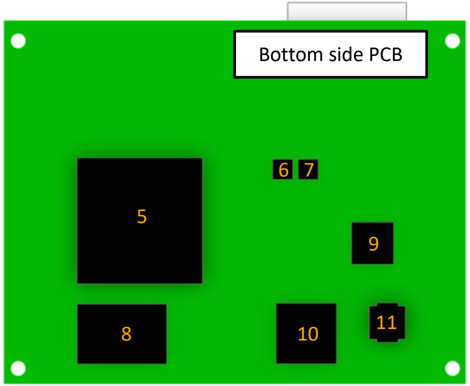
Cover

Screws

TIE M+ 2023 Subject

PCB Layout

			Physical properties				
No.	Name	Power [W]	Temp. limit [°C]	Thermal conductivity [W/mK]	Specific heat [J/kgK]	Density [kg/m^3]	Emessivity [-]
1	Power supply 1	0.1	150	18 18 1.3	795	1900	0.9
2	Power supply 2	0.22	175	18 18 1.3	795	1900	0.9
3	Power supply 3	0.1	175	18 18 1.3	795	1900	0.9
4	Power supply 4	0.1	175	18 18 1.3	795	1900	0.9
5	Processor	4	115	55 55 1.15	795	1900	0.9
6	Power supply 5	0.3	150	18 18 1.3	795	1900	0.9
7	Power supply 6	0.15	150	18 18 1.3	795	1900	0.9
8	Memory	0.3	125	47 47 1.3	795	1900	0.9
9	Power supply 7	0.1	150	18 18 1.3	795	1900	0.9
10	QFN	0.3	150	26 26 1.7	795	1900	0.9
11	Diode	0.2	150	22 22 1.5	795	1900	0.9

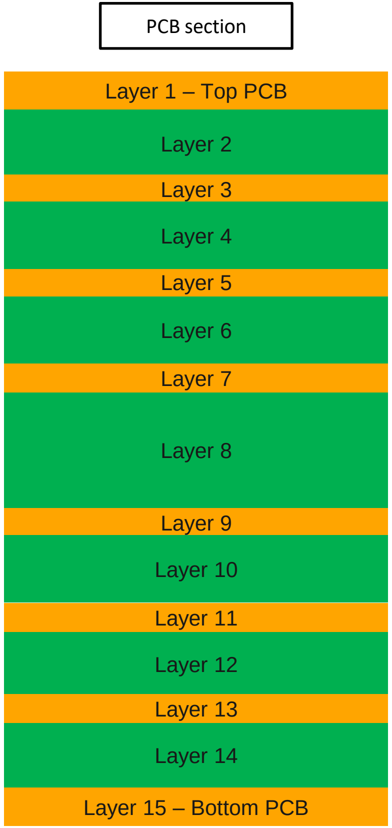


TIE M+ 2023 Subject

PCB Thermal conductivity - orthotropic

Layer Details		Area [%]	
No. Layers	t [μm]	Cu [%]	Dielectric [%]
1	40	0.80	0.20
2	70	0.00	1.00
3	30	0.60	0.40
4	70	0.00	1.00
5	30	0.70	0.30
6	70	0.00	1.00
7	30	0.80	0.20
8	920	0.00	1.00
9	30	0.70	0.30
10	70	0.00	1.00
11	30	0.70	0.30
12	70	0.00	1.00
13	30	0.60	0.40
14	70	0.00	1.00
15	40	0.80	0.20

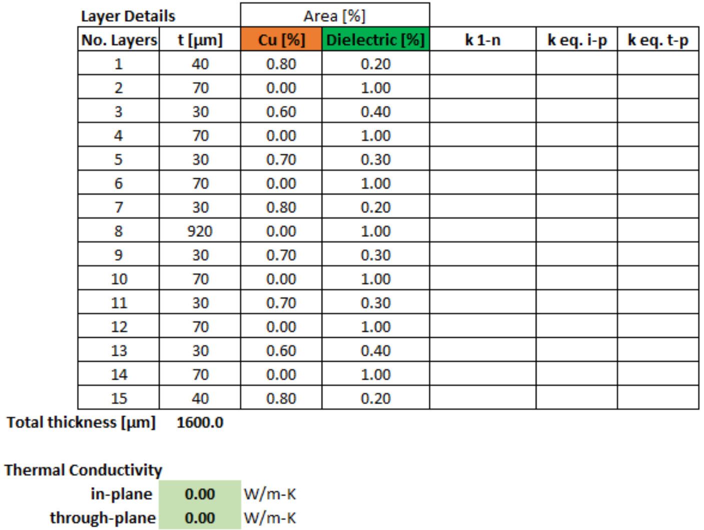
Total thickness [μm] **1600.0**



TIE M+ 2023 Subject

PCB Thermal conductivity - orthotropic

With these equations, the equivalent orthotropic thermal conductivity of the PCB must be calculated.



Layer Details

		Area [%]				
No. Layers	**t [µm]**	**Cu [%]**	**Dielectric [%]**	**k 1-n**	**k eq. i-p**	**k eq. t-p**
1	40	0.80	0.20			
2	70	0.00	1.00			
3	30	0.60	0.40			
4	70	0.00	1.00			
5	30	0.70	0.30			
6	70	0.00	1.00			
7	30	0.80	0.20			
8	920	0.00	1.00			
9	30	0.70	0.30			
10	70	0.00	1.00			
11	30	0.70	0.30			
12	70	0.00	1.00			
13	30	0.60	0.40			
14	70	0.00	1.00			
15	40	0.80	0.20			

Total thickness [µm] **1600.0**

Thermal Conductivity

in-plane	**0.00**	W/m-K
through-plane	**0.00**	W/m-K

$$k_{in-plane} = k_1 \frac{t_1}{t_{total}} + k_2 \frac{t_2}{t_{total}} + \cdots + k_n \frac{t_n}{t_{total}}$$

$$k_{through-plane} = t_{total} / \frac{t_1}{k_1} + \frac{t_2}{k_2} + \cdots + \frac{t_n}{k_n}$$

$$k_{1-n} = k_{Cu} A_{Cu}\% + k_{die} A_{die}\% + k_{air} A_{air}\%$$

$t_{1-n} = thickness\ layer$

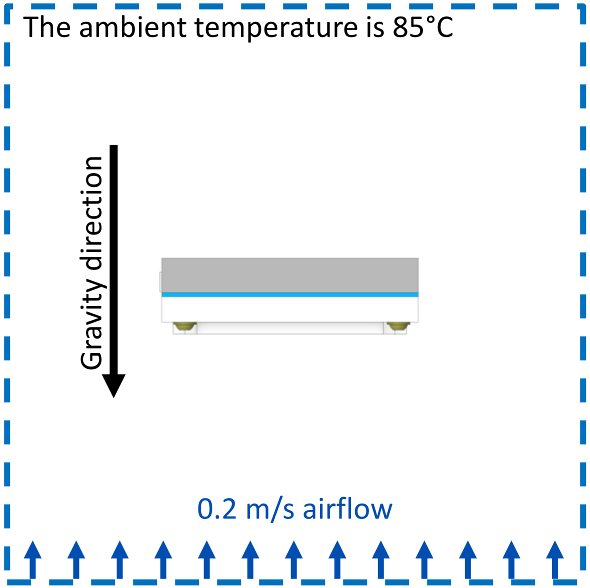
$t_{total} = thickness\ PCB$

$A = Area$

TIE M+ 2023 Subject

Boundary Conditions

Low velocity

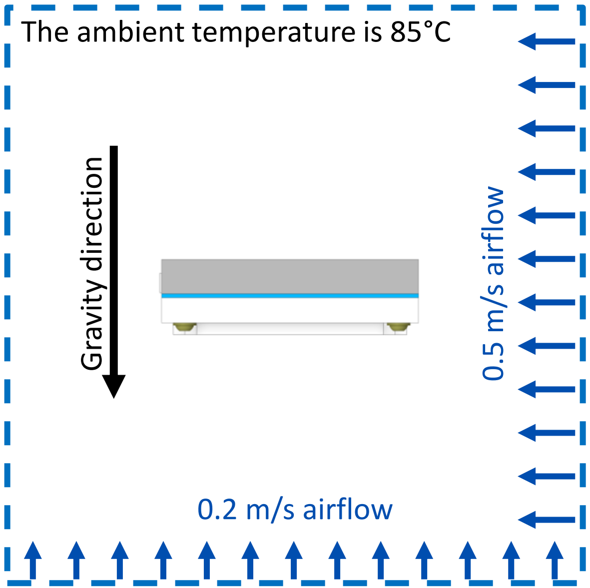


The ambient temperature is 85°C

Gravity direction

0.2 m/s airflow

High velocity



The ambient temperature is 85°C

Gravity direction

0.5 m/s airflow

0.2 m/s airflow

TIE M+ 2023 Subject

Calculation of thermal resistance

- What is thermal resistance?

$$R_{th} = \frac{Self\ heating\ [K]}{Total\ power\ [W]}$$

$$Self\ heating [K] = Average\ temparature\ [°C] - Ambient\ temperature\ [°C]$$

$$Average\ temparature\ [°C] - electronic\ components$$

Object	Power [W]	Temp. limit [°C]	Junction temperature [°C] Low velocity Natural surface
Carrier	-	-	
Cover	-	-	
PCB	-	-	
Processor	4.00	115	
Memory	0.30	125	
Diode	0.20	150	
Power Supply 2	0.10	150	
Power Supply 3	0.15	175	
Power Supply 4	0.30	175	
Power Supply 5	0.22	150	
Power Supply 6	0.10	150	
Power Supply 7	0.10	150	
Power Supply 8	0.10	150	
QFN	0.30	150	
Total Power [W]	**5.87**		

Ambient temparature [°C]	
Average temparature [°C]	
Self heating [K]	
Thermal resistance [K/W]	

TIE M+ 2023 Subject

No.	Requirements
1	Defining new project, working folder structure and naming (TIE-M Plus Thermal 2023)
2	Importing geometry into the simulation tool
3	Setting and creating materials (solid and surface material)
4	Calculate the orthotropic equivalent thermal conductivity of the PCB and use it as input for the simulation
5	Power setting (it will be set on volume)
6	Boundary condition settings (airflow, temperature and gravity)
7	Meshing creation (minimum two elements per part thickness) - one slide with the critical area a cross-section showing the mesh
8	Setting monitoring points for all electronic components
9	Settings for solving (solution convergence data plot)
10	You will have to run 4 solutions
10.1	Low velocity with Al commercial surface on Carrier and Cover
10.2	High velocity with Al commercial surface on Carrier and Cover
10.3	Low velocity with Al anodized surface on Carrier and Cover
10.4	High velocity with Al anodized surface on Carrier and Cover
11	Plotting the maximum temperature of electronic components
12	Plotting the average temperature on the mechanical components (Cover, Carrier, PCB)
13	Calculation of the thermal resistance of the entire sensor for each solution
14	Sectional plotting of temperature and velocity distribution
15	Plotting the temperature distribution of the PCB and the electronic components (top and bottom view)
16	Plotting the temperature distribution of Carrier and Cover
16	Defining the optimal cooling design considering the input data
17	Conclusions on the thermal analysis you have done

Thank you
for your attention!