Thermal Management Concept of a Taxi Vehicle with Rear Engine Application

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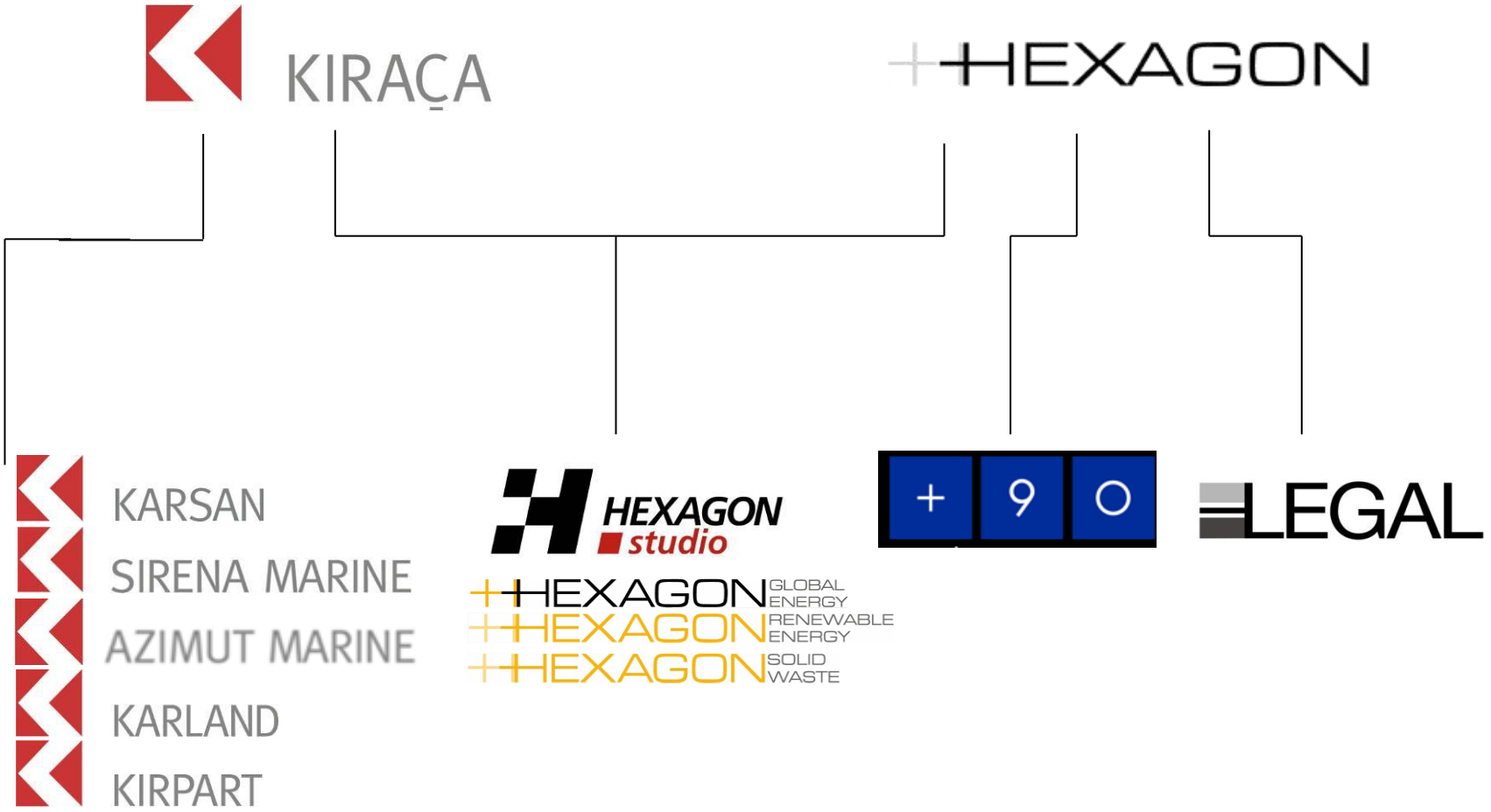

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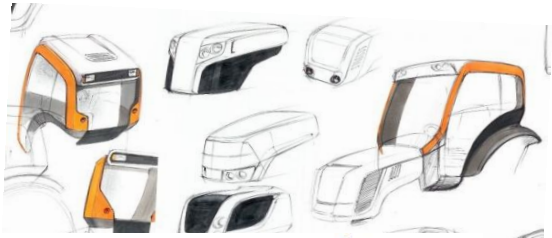

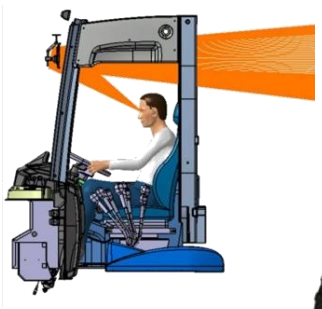

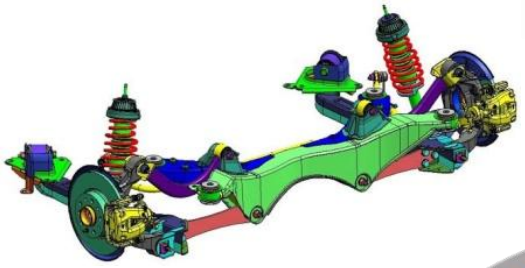
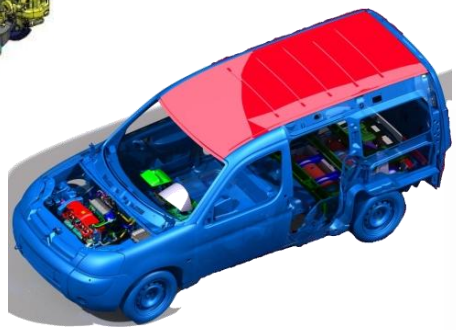

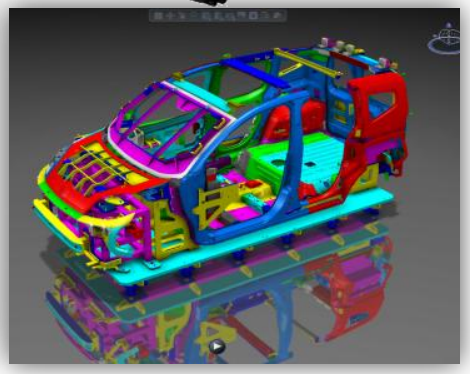
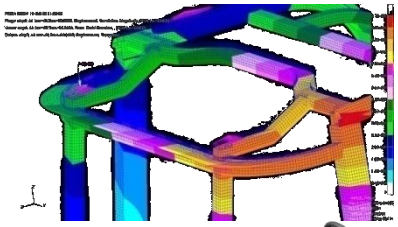
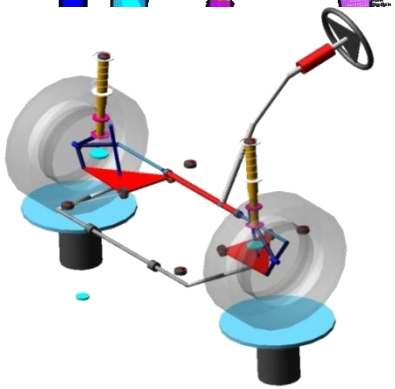
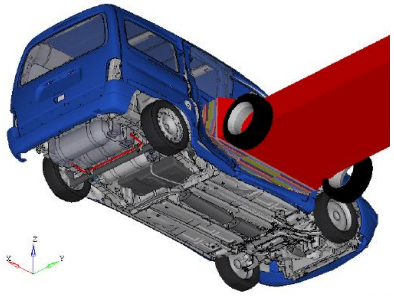

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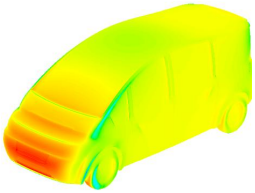
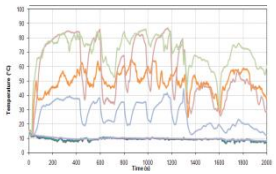
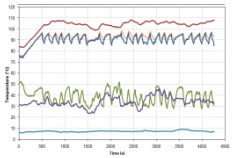
OUTLINE

1. Introduction
2. Design Properties
3. Analysis
   - 3.1. Aerodynamic Analysis
   - 3.2. Engine Cooling Analysis
4. Prototype Test
   - 4.1. Front Engine Vehicle (Donor)
   - 4.2. Rear Engine Vehicle (First Attribute Prototype - AP0)
5. Results
6. Future Works







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INTRODUCTION

Aim: Powertrain cooling studies on a new design rear engine rear wheel drive vehicle

Literature:

- Mostly used in sport cars.
- Only a few passenger cars.
- Two rear engine cooling system design configurations:
  - 1- Radiator is mounted in the same position as a front engine vehicle (e.g. Smart FourTwo).
  - 2- Two small radiators are mounted on the left and right sides of the engine. (e.g. Tatra)

Karsan V1 project:

- But these are not applicable in this project
  - 1 - Radiator cannot be mounted in front of the vehicle
    - requirements of the luggage volume
    - restrictions of the routing and length of the cooling hoses
  - 2 - Side mounted radiators are rejected because of the limited space

Result: Mounted in the rear of the vehicle and also at the rear of the engine.

DESIGN PROPERTIES

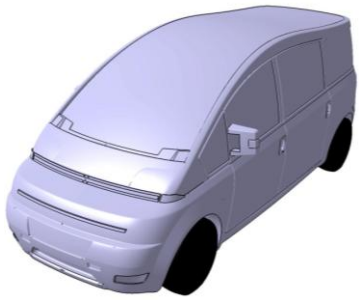
Vehicle Properties	
Vehicle Weight	2700 kg
Ground Clearance	200 mm
Frontal Area	3.085 m^2
Wheelbase	3260 mm
Trackwidth	1580 mm
Vehicle Length	4830 mm
Vehicle Height	1920 mm
Vehicle Width	1922 mm
Design Intend	Urban usage, taxi
Average Speed	25 km/h
(Average speed of a taxi when looking for a fare is about 11 km/h)	
Required Maximum Speed	110 km/h
Stationary Waiting Time	40 %

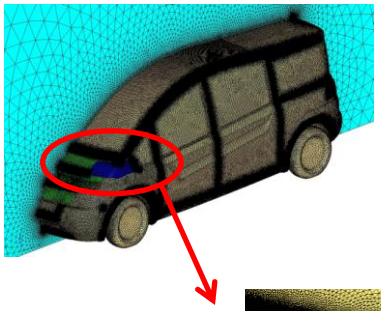
Engine Properties	
Engine Fuel	Gasoline
Engine Displacement	2360 cc
Engine Power	129 kW (@ 6000 rpm)
Engine Torque	225 Nm (@ 4400 rpm)

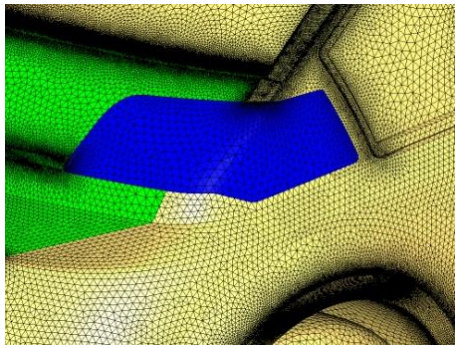
Cooling Requirements (Predicted)	
Component	**Heat Dissipation Rate**
Engine	40 kW
Radiator	100 kW

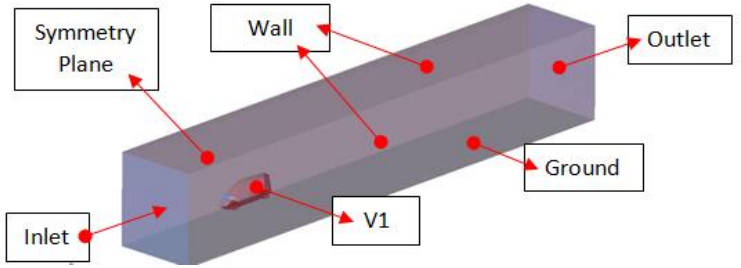
ANALYSIS / AERODYNAMICS

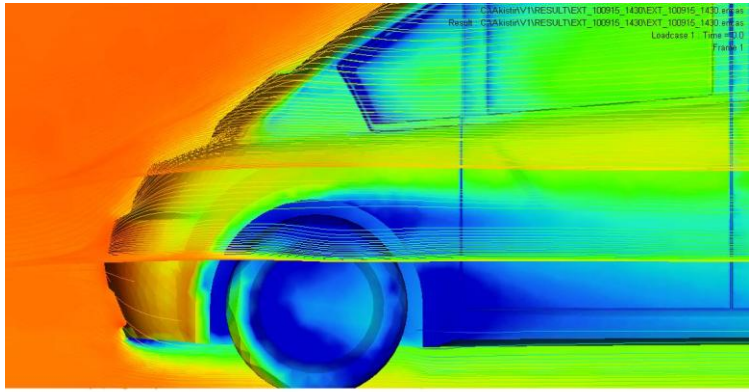
Analysis Properties	
Model	Pressure based, steady
Turbulence model	k-ε, realizable
Mesh Count	~4 million
Velocity Inlet (km/h)	25 & 90



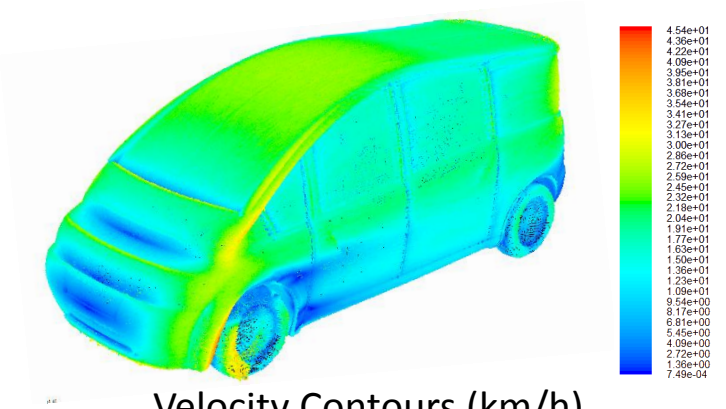




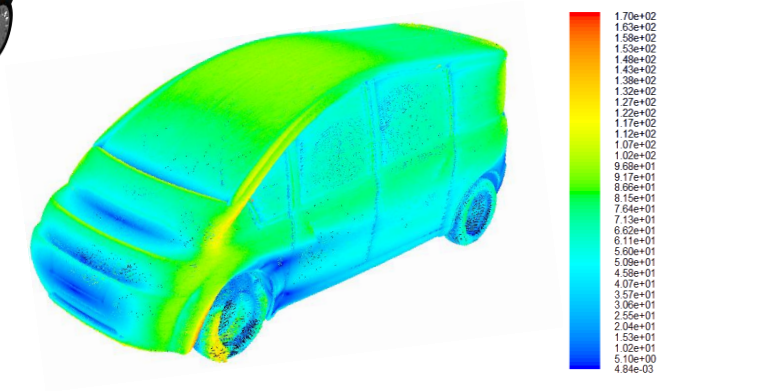




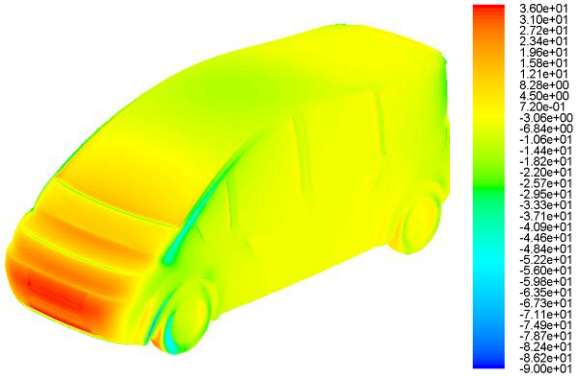
ANALYSIS / AERODYNAMICS



Velocity Contours (km/h)

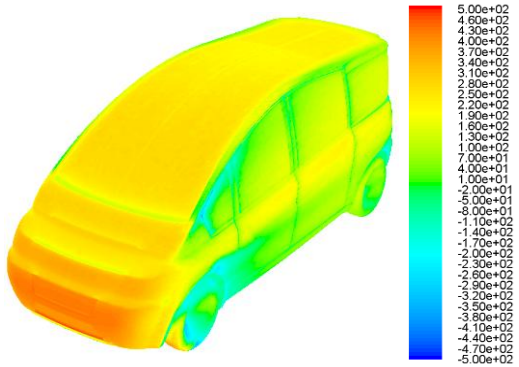


Velocity Contours (km/h)



Pressure Contours (Pa)

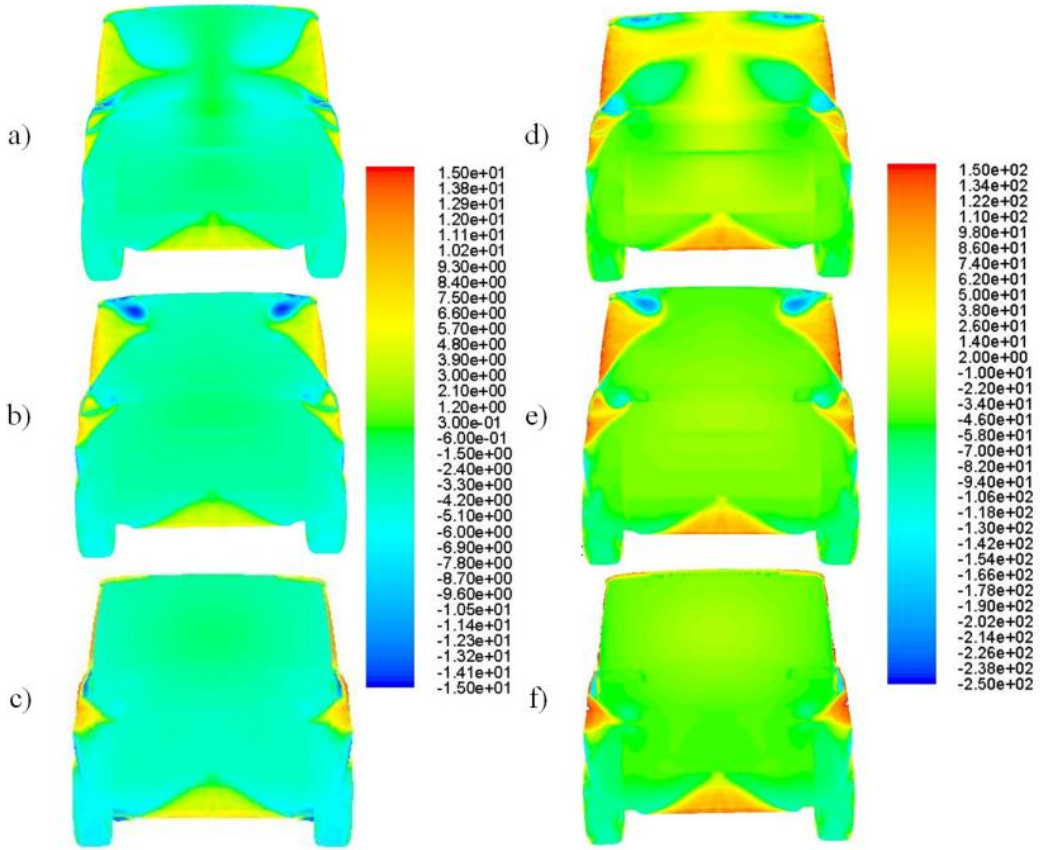
25 km/h



Pressure Contours (Pa)

90 km/h

ANALYSIS / AERODYNAMICS



a) Original (@ 25 km/h)

b) With Spoiler (@ 25 km/h)

c) With D-pillar Spoiler (@ 25 km/h)

d) Original (@ 90 km/h)

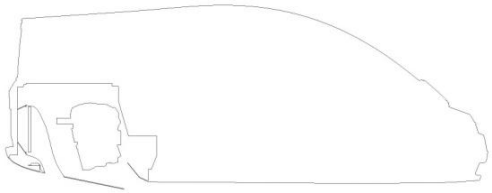
e) With Spoiler (@ 90 km/h)

f) With D-pillar Spoiler (@ 90 km/h)

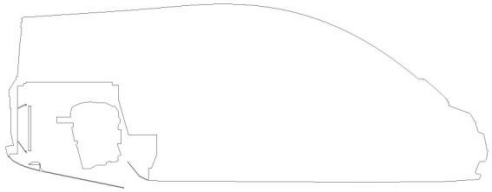
Version	Cd
Original	0.412
With Spoiler	0.404
With D-pillar Spoiler	0.397
Cooling Air Discharge	0.390

ANALYSIS / ENGINE COOLING

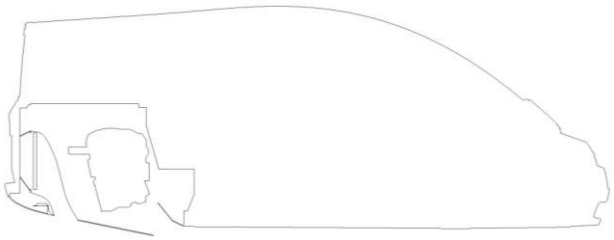
Separated

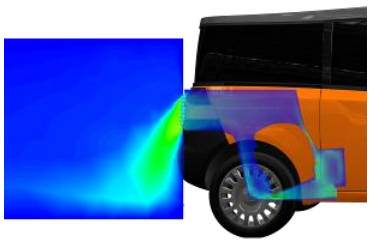


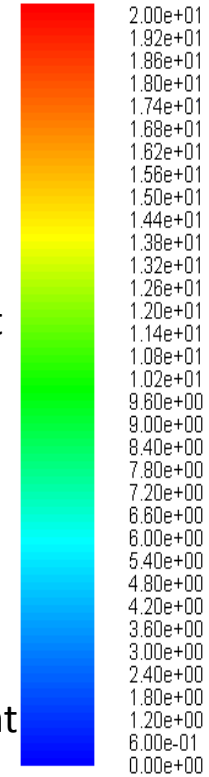
Combined



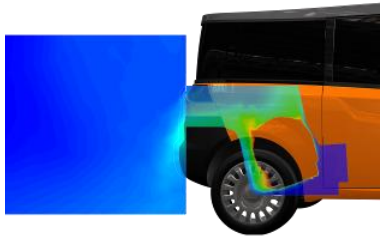
ANALYSIS / ENGINE COOLING

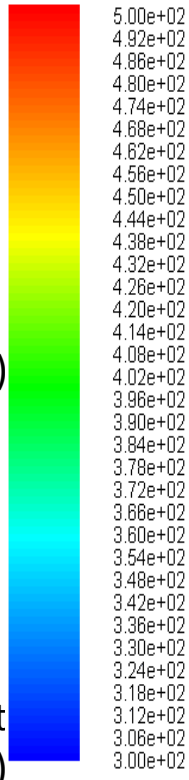




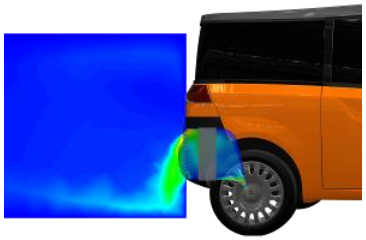


a) Engine compartment velocity contours (m/s)

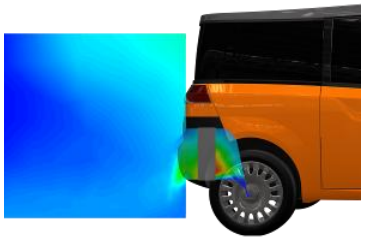




b) Engine compartment temperature contours (K)

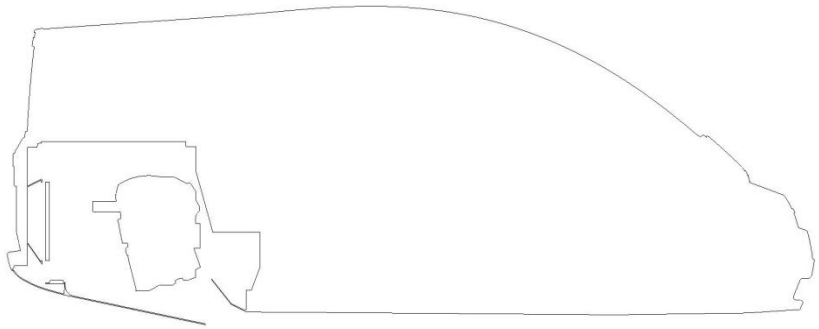


c) Radiator compartment velocity contours (m/s)



d) Radiator compartment temperature contours (K)

ANALYSIS / ENGINE COOLING

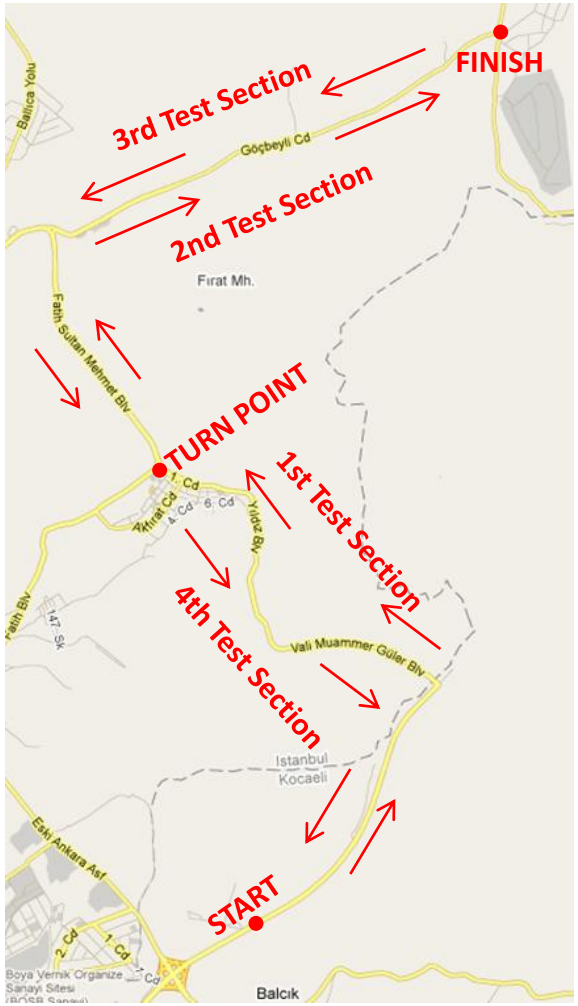


Temperature contours (K) of cooling analysis results of combined engine and radiator compartments

PROTOTYPE TESTS

All thermal management tests were performed on the same road over the same distance.

Test track	8 km (out and return)
Test count	Two subsequent tests were performed
Test conditions	1st gear 25 km/h vehicle velocity
	2nd gear 40 km/h vehicle velocity



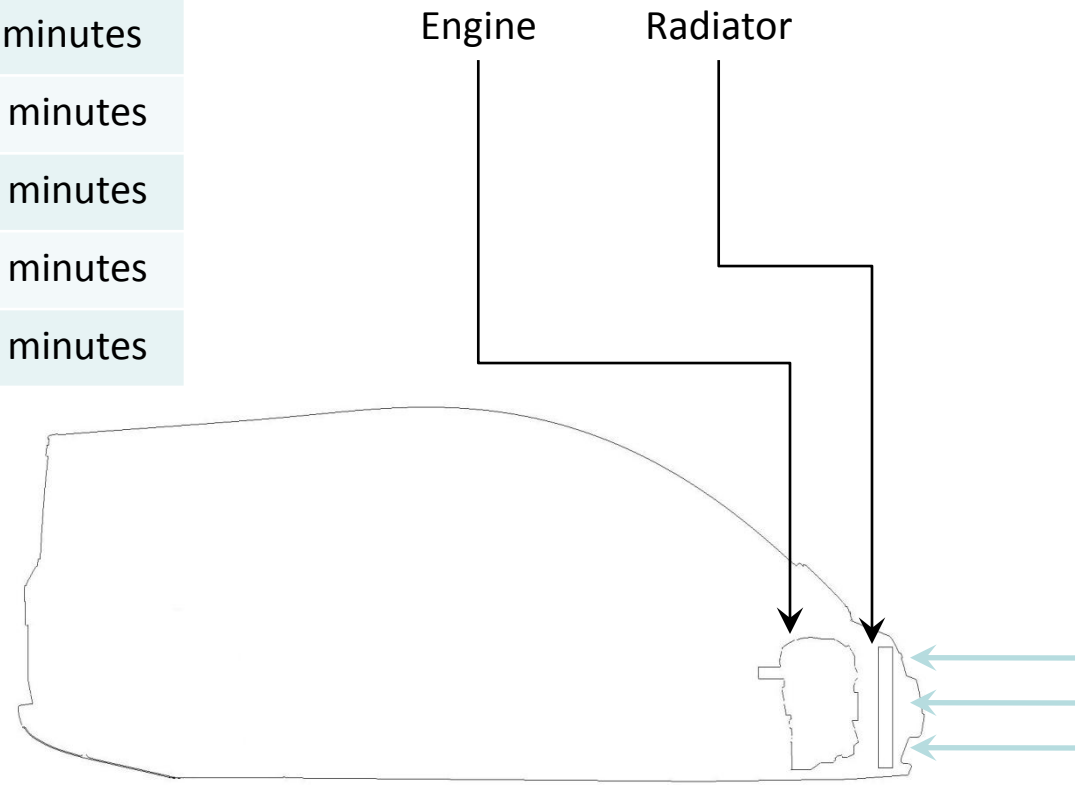
PROTOTYPE TESTS / FRONT ENGINE

Donor vehicle properties		
Engine Displacement	2000 cc	
Max. Power	88 kW (@ 4000 rpm)	
Max. Torque	300 Nm (@ 2000 rpm)	
Radiator Dimensions	700 mm x 400 mm	
Fan Dimensions	1st fan	9 blades Ø: 360mm Air velocity: 7 m/s
	2nd fan	6 blades Ø: 325mm Air velocity: 7 m/s

Temperature Measuring Points
Oil dipstick
Coolant temperature @ engine in and out
Air temperature before radiator
Air temperature before intercooler
Air temperature after radiator
Air temperature after intercooler
Temperature above ECU
Under bonnet temperature (above the engine)
Temperature above the heat shield of the catalytic
Total thermocouples: 18

PROTOTYPE TESTS / FRONT ENGINE

Test Properties	
Ambient Temperature	12 °C
Test Weight	2700 kg
Test Duration	142 minutes
First Test Section	22.0 minutes
Second Test Section	13.3 minutes
Third Test Section	13.5 minutes
Fourth Test Section	22.2 minutes



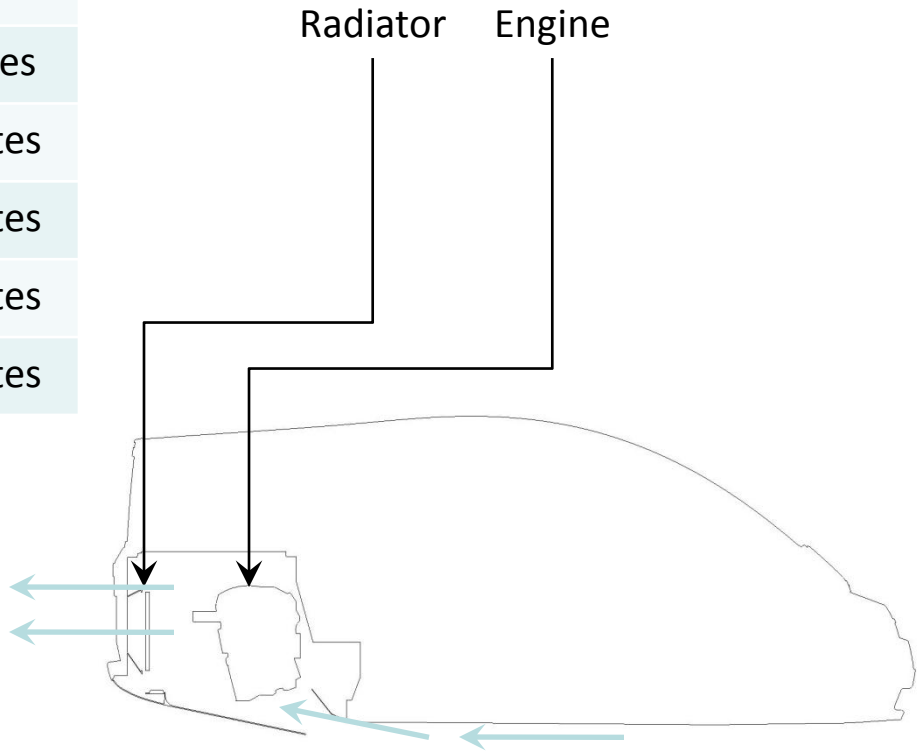
PROTOTYPE TESTS / FRONT ENGINE

Condition	Thermocouple Location	Maximum Temperature (°C)
1st Gear 25 km/h	Oil Dipstick	113.7
	Coolant Inlet	91.0
	Coolant Outlet	111.0
	Radiator Inlet 1	13.8
	Radiator Inlet 2	15.5
	Radiator Inlet 3	14.0
	Radiator Inlet 4	14.5
	Inletcooler Inlet 1	16.0
	Inletcooler Inlet 2	16.1
	Radiator Outlet 1	42.8
	Radiator Outlet 2	87.9
	Radiator Outlet 3	89.1
	Radiator Outlet 4	86.2
	Inletcooler Outlet 1	45.8
	Inletcooler Outlet 2	51.1
	ECU	32.2
	Underhood	55.2
	Catalytic Converter	78.8

Condition	Thermocouple Location	Maximum Temperature (°C)
2nd Gear 40 km/h	Oil Dipstick	111.1
	Coolant Inlet	84.0
	Coolant Outlet	102.4
	Radiator Inlet 1	10.7
	Radiator Inlet 2	9.9
	Radiator Inlet 3	10.1
	Radiator Inlet 4	10.6
	Inletcooler Inlet 1	10.4
	Inletcooler Inlet 2	10.0
	Radiator Outlet 1	44.6
	Radiator Outlet 2	78.9
	Radiator Outlet 3	83.2
	Radiator Outlet 4	78.1
	Inletcooler Outlet 1	40.1
	Inletcooler Outlet 2	44.0
	ECU	32.4
	Underhood	44.4
	Catalytic Converter	65.9

PROTOTYPE TESTS / REAR ENGINE

Test Properties	
Ambient Temperature	8 °C
Test Weight	2700 kg
Test Duration	142 minutes
First Test Section	22.6 minutes
Second Test Section	13.5 minutes
Third Test Section	14.0 minutes
Fourth Test Section	21.1 minutes



PROTOTYPE TESTS / REAR ENGINE

Condition	Thermocouple Location	Maximum Temperature (°C)
1st Gear 25 km/h	Oil Dipstick	107.9
	Coolant Inlet	96.7
	Coolant Outlet	97.8
	Radiator Inlet 1	54.6
	Radiator Inlet 2	50.7
	Radiator Inlet 3	50.7
	Radiator Inlet 4	36.5
	Inletcooler Inlet 1	40.9
	Inletcooler Inlet 2	34.3
	Radiator Outlet 1	74.3
	Radiator Outlet 2	72.4
	Radiator Outlet 3	76.1
	Radiator Outlet 4	46.6
	Inletcooler Outlet 1	48.0
	Inletcooler Outlet 2	45.1
	ECU	35.5
	Underhood	56.6
	Catalytic Converter	65.2

Condition	Thermocouple Location	Maximum Temperature (°C)
2nd Gear 40 km/h	Oil Dipstick	108.2
	Coolant Inlet	96.8
	Coolant Outlet	98.7
	Radiator Inlet 1	57.4
	Radiator Inlet 2	52.4
	Radiator Inlet 3	39.2
	Radiator Inlet 4	35.0
	Inletcooler Inlet 1	43.1
	Inletcooler Inlet 2	38.1
	Radiator Outlet 1	70.5
	Radiator Outlet 2	72.7
	Radiator Outlet 3	74.1
	Radiator Outlet 4	75.3
	Inletcooler Outlet 1	46.2
	Inletcooler Outlet 2	45.2
	ECU	29.4
	Underhood	51.8
	Catalytic Converter	44.1

PROTOTYPE TESTS / RESULTS

	Front engine	Rear engine
Ambient temperature	>	
Maximum engine coolant outlet	>	
Maximum engine coolant inlet	<	
Coolant temperature decrease through radiator	>	
Air temperature increase through radiator	>	
Radiator inlet air temperature	<	
Oil temperature	>	
Underhood & ECU (1st gear)	~	
Underhood (2nd gear)	<	
Catalytic	>	

- When the vehicle velocity increases, cooling performance gets better for the front engine vehicle but remains the same for the rear engine vehicle.
- Since the engine compartment is not a sealed volume, air taken from the bottom of the vehicle escapes from undesired openings, especially halfshaft openings.

FUTURE WORK

- Road heat management tests (different engine speeds and at different loading conditions)
- Side cooling air intake rear grill
- Engine and radiator compartment separation options
- Detailed cooling analysis
- New prototype build-up (AP1) with representative engine and body
- ATB tests

THANK YOU FOR LISTENING