CENTRO NAZIONALE PER LA MOBILITÀ SOSTENIBILE

Spoke 2 WP 1.2

Definition of ADAS sensors architecture for MOST vehicle prototypes

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NextGenerationEU

CENTRO NAZIONALE PER LA MOBILITÀ SOSTENIBILE

Politecnico di Torino

Department of Mechanical and Aerospace Engineering

Master's Degree in Mechanical Engineering

Sensors Architecture Definition for Energy Consumption Reduction of Battery Electric Vehicles

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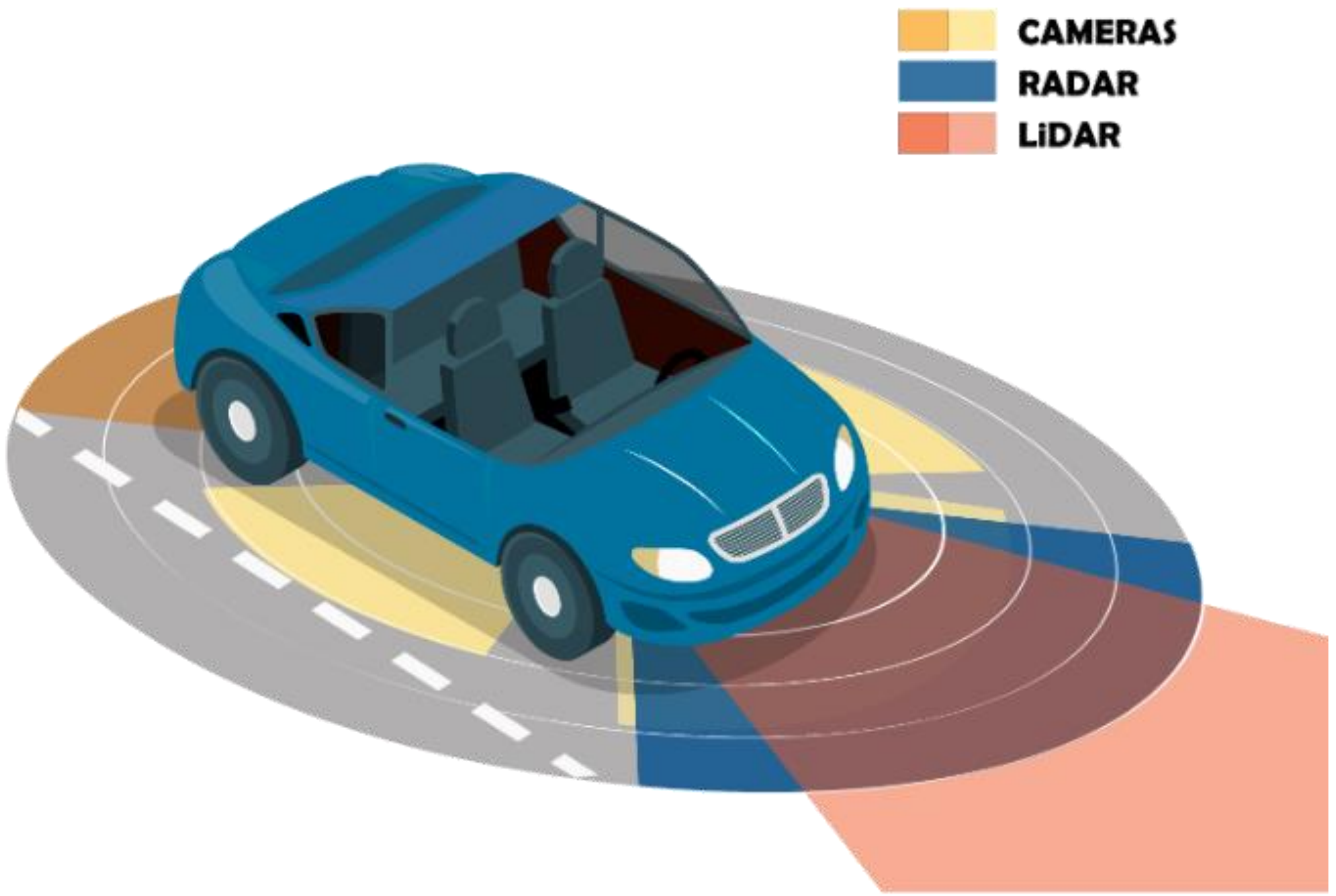
SENSORS CONFIGURATION:

I) Evolution Kit

- Solid State Lidar
- Camera
- Radar (LRR)

II) Baseline Kit

- Stereoscopic Camera
- Radar (SRR & LRR)



Source: https://www.mdpi.com/1424-8220/23/2/601

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NEW ADAS Architecture Requirements

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Case Study: 500e with NEW ADAS sensors and features (additional to OEM)

ADAS SENSORS

Sensors' Features	*Interfaces / Communication*	*Additional Features*
Range 0 – 200 [m]	**CAN / ETH**	Automotive-grade
Resolution – depends on functions	ROS Integration is a plus	Functional Safety compliance (opt)

INTERFACE

Operating System	*Interfaces / Communication*	*Additional Features*
Linux – ROS / ROS2	**CAN / ETH**	Automotive-grade
Autoware integration is a plus	USB	Functional Safety compliance (opt)

CONTROL

Standard Functions	*Detection Functions*		*Semi-Autonomous Functions*
Adaptive Cruise Control (ACC)	Lane-Change-Assist	Lane-Support-Functions	**Traffic-Jam-Assist**
Lane Keeping Assist Systems (LKAS)	Speed-Limit-Assist		**Highway Assist**

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REQUIREMENTS FOR LIDAR SENSORS

Case Study: 500e with NEW ADAS sensors and features (additional to OEM)

- **Field of View.** We aim at a **horizontal FOV** of more that **100°** and a **vertical FOV** of more that **10°** to reduce the number of sensors that has to mounted on the vehicle.
- **Resolution and number of scan lines.** The sensors should have a **high resolution below 0.4°** and **at least five scan lines** to be able to detect the Lidar targets and a real-world objects.
- **Update rate or frame rate.** In order to avoid longer delays in the object detection, the sensor systems should have an update **frequency** or frame rate of **more than 5 Hz**.
- **ROS/ROS2 support.** For an easy integration into our control software stack, a **Linux-based system** implementation and an AD framework based on **ROS2** is preferred.
- **Robustness of sensor system.** The test candidates should work well also in **tougher weather conditions**, and the sensor performance should not notably degrade under those conditions.

Source: https://www.mdpi.com/1424-8220/22/19/7146

BENCHMARK SOLID STATE LIDAR:

Automotive Products:

	Livox Horizon	Robosense M1	Blickfeld Cube	Blickfeld Cube Range	Velodyne Velarray H800	Innoviz Pro
Picture						
Scan pattern						
Framerate	10 Hz	10 Hz	6.3 Hz	5.7 Hz	25 Hz	16 Hz
Points per Frame	24.000	78.750	8.829	7.599	16.181	15.500
FOV	81.7° H, 25.1° V	120° H, 25° V	72° H, 30° V	18° H, 12° V	120° H, 16° V	72° H, 18.5° V
Principle	Rotating Prisms	MEMS	MEMS	MEMS	Solid State	MEMS

Source: https://www.mdpi.com/1424-8220/22/19/7146

BENCHMARK SOLID STATE LIDAR:
Automotive-grade LiDAR:

	Livox Horizon	Robosense RS M1	Blickfeld cube-1	Velodyne Velarray H800	Innoviz Pro	Hesai AT128 10/20 Hz
Detection range	260 m	200 m	250 m	200 m	135 m	200 m; 1,536,000 points/s
FOV / Resolution	81.7°H; 0.3°H 25.1°V; 0.03°V	120°H; 0.2°H 25.1°V; 0.2°V	70°H; 0.4°H 30°V; 0.5°V	120°H; 0.2°H 16°V; 0.4°V	72°H; 0.18°H 18.5°V; 0.4°V	120°H; 0.1°H 25.4°V; 0.2°V
Communication Protocols	CAN/ETH	CAN/ETH	CAN/ETH/ RJ45	CAN/ETH	CAN/ETH	CAN/ETH
ADAS applications	ACC, LKAS	ACC, LKAS, Traffic Jam	ACC, LKAS	ACC, LKAS, Emergecy Braking	ACC, LKAS,	ACC, LKAS, Traffic Jam
Production Year	2021	2020	2020	2020	2019	2022
Cost	1050	4650	3999	500	1000	2900

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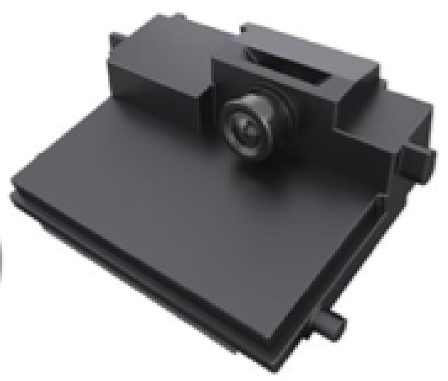
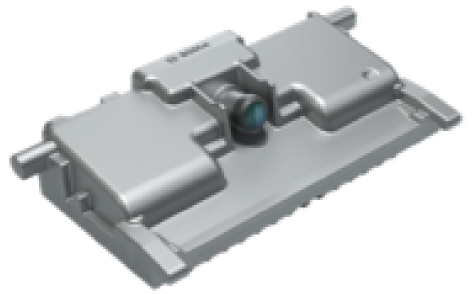
BENCHMARK EVOLUTION KIT:

Camera sensors:





	Leopard Imaging AR0231	Leopard Imaging IMX390	NileCam21 CUXVR GMSL2	Sony STURD-eCam31	Continental MONO-Camera	BOSCH Multi Purpose Camera
Pixel size	3.0 μm x 3.0 μm	3.0 μm x 3.0 μm	3.0 μm x 3.0 μm	3.0 μm x 3.0 μm	3.0 μm x 3.0 μm	3.0 μm x 3.0 μm
FOV	122°H; 74°V	122°H; 74°V	111°H; 62°V	111°H; 62°V	110°H; 70V	100°H; 48°V
Resolution	1928H; 1208V	1937H; 1217V	2048H; 1280V	1937H; 1553V	1280H; 960V	2048H; 1280V
ADAS applications	ACC, LKAS, AEB	ACC, LKAS, AEB	ACC, LKAS, AEB	ACC, LKAS, AEB, Traffic Jam	ACC, LKAS, AEB, Traffic Jam	ACC, LKAS, AEB, LDW Traffic Jam
Production Year	2019	2023	2021	2021	2022	2021
Cost [€]	662	662	505	460	550	600

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BENCHMARK EVOLUTION KIT:

Radar LRR sensors:

	CONTINENTAL ARS 408	CONTINENTAL ARS 430	APTIV FLR4+	BOSCH LRR5 FRONT RADAR
Detection Range	250 m	250 m	300 m	300 m
Range Accuracy	±0.4m far ±0.2m near	±0.37m far ±0.1m near	±0.2m far ±0.1m near	±0.41m far ±0.11m near
Velocity Resolution	0.10 m/s far 0.12 m/s near	0.1 m/s far 0.11 m/s near	0.06 m/s far 0.06 m/s near	0.04 m/s far 0.17 m/s near
ADAS applications	ACC, LKAS, AEB	ACC, LKAS, AEB	ACC, LKAS, AEB, Traffic Jam	ACC, LKAS, AEB
Production Year	2021	2021	2022	2021
Cost [€]	240	240	-	299

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BENCHMARK EVOLUTION KIT:
4D Radar sensors:

	CONTINENTAL ARS 548 RDI	VEOONER - ARBE	ZF Imaging Radar	APTIV FLR7
Detection Range	300 m	-	350 m	290 m
Range Accuracy	±0.15 m	-	±0.6 m	±0.2 m
Velocity Resolution	0.10 m/s	-	-	0.06 m/s
ADAS applications	ACC, LKAS, AEB	ACC, LKAS, AEB		ACC, LKAS, AEB
Production Year	2023	2022	2022	2022
Cost [€]	-	-	-	-

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BENCHMARK BASELINE KIT:

Radar SRR sensors:

	CONTINENTAL SRR308	CONTINENTAL SRR520	TEXAS INSTRUMENTS AWRL6432	XENSIV™ BGT60ATR24C
Detection Range	95 m	100 m	25 m	18 m
Range Accuracy	±0.2 m far ±0.5 m near	±0.22 m far ±0.5 m near	High	High
Velocity Resolution	0.33 m/s	0.35 m/s	Ultra high	High
ADAS applications	LKAS, AEB	LKAS, AEB	LKAS, AEB, Traffic Jam	LKAS, AEB
Production Year	2021	2021	2021	2022
Cost [€]	50	50	-	30

BENCHMARK BASELINE KIT:

Stereoscopic camera sensors:

	Leopard Imaging AR0144	Leopard Imaging AR0234CS	Leopard Imaging OV580	ZED 2i 60 fps	ZED X 60 fps	ZED mini 60 fps
Depth range	8 m	8 m	10 m	20 m	20 m	15 m
FOV	59°H; 36°V	121.5°H; 73.5°V	100°H; 60°V	110°H; 70°V	110°H; 80V	90°H; 60°V
Resolution	1280H; 800V	1920H; 1200V	1280H; 720V	1280H; 720V	1920H; 1200V	1280H; 720V
Baseline	7 cm	9 cm	9 cm	12 cm	12 cm	6.3 cm
Production Year	2020	2022	2020	2022	2022	2022
Cost [€]	280	370	460	460	550	370

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SOLUTIONS OVERVIEW:
Automotive-grade:

	Solid State Lidar / Radar 4D	Stereo Camera	Radar Short Range	Camera	Costs [€]	REQUIREMENTS [%]	CRITICAL REQUIREMENTS [%]
Kit 1	Continental ARS 548 RDI	ZED X	Continental SRR 520	NILecam25 CUXVR GMLS2	5100	92	92
Kit 2	Robosense RS M1	ZED X	Continental SRR 520	NILecam25 CUXVR GMLS2	6100	92	92
Kit 3	Continental ARS 548 RDI	-	Continental SRR 520	NILecam25 CUXVR GMLS2	6070	90	89

	COSTS [€]					REQUIREMENTS [%]					CRITICAL REQUIREMENTS				
	LiDAR / Radar 4D	Stero Camera	Radar Short Range	Camera	Tot.	LiDAR / Radar 4D	Stero Camera	Radar Short Range	Camera	Tot.	LiDAR / Radar 4D	Stero Camera	Radar Short Range	Camera	Tot.
Kit 1	4000	550	50	505	5100	100	100	83	86	92	100	100	67	100	92
Kit 2	5000	550	50	505	6100	100	100	83	86	92	100	100	67	100	92
Kit 3	4000	-	50	505 * 4	6070	100	-	83	86	90	100	-	67	100	89

SOLUTIONS REQUIREMENTS:

Automotive-grade: Evolution kit

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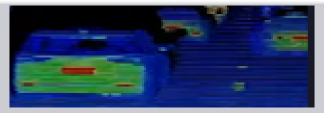
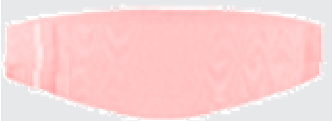
SOLID STATE LIDAR TOTAL REQUIREMENTS

	Range 200m	Frame Rate 5 Hz	Resolution 0.4°H; 0.4°V	Scan Pattern	Points per Frame
Robosense RS M1	200 m	10 Hz	0.2°H; 0.2°V		78,750
Hesai AT128	200 m	10/20 Hz	0.1°H; 0.2°V		1,536,000
Blickfeld cube-1	250 m	6.3 Hz	0.4°H; 0.5°V		8,829
Velodyne Velarray	200 m	25 Hz	0.2°H; 0.4°V		16,181
Livox Horizon	260 m	10 Hz	0.03°H; 0.28°V		15,500
Innoviz Pro	135 m	16 Hz	0.18°H; 0.4°V		24,000

RADAR LRR TOTAL REQUIREMENTS

	Speed Resolution	Distance Range 200m	ADAS application
Aptive FLR4+	0.06 m/s	300 m	LKAS, ACC, Traffic Jam, AEB
Continental ARS - 548	0.10 m/s	300 m	LKAS, ACC, AEB
Continental ARS - 430	0.10 m/s	250 m	LKAS, ACC, AEB
Bosch Front Radar	0.04 m/s	300 m	LKAS, ACC, AEB
Continental ARS - 408	0.10 m/s	250 m	LKAS, ACC, AEB
Bosch LRR5	0.04 m/s	300 m	LKAS, ACC, AEB

CAMERA TOTAL REQUIREMENTS

	FOV	ADAS application	Resolution
Continental Mono Camera	110H; 70°V	ACC, LKAS, AEB Traffic Jam	1280H; 960V
Bosch Multi Camera	100°H; 48°V	ACC, LKAS, AEB Traffic Jam	2048H; 1280V
Sony STURDeCam31	111°H; 62°V	ACC, LKAS, AEB Traffic Jam	1937H; 1553V
Chameleon3 USB3	120°H; 70°V	ACC, LKAS, AEB	1280H; 1024V
Grasshoper3 USB3	111°H; 72°V	ACC, LKAS, AEB	1920H; 1200V
Leopard Imaging IMX390	122°H; 74°V	ACC, LKAS, AEB	1937H; 1217V

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SOLUTIONS REQUIREMENTS:
Automotive-grade: Baseline kit

STEREOSCOPIC CAMERA TOTAL REQUIREMENTS			
	Resolution	Depth Range	FOV
Leopard Imaging AR0144	1280H; 800V	8 m	59°H; 36°V
Leopard Imaging AR0234CS	1920H; 1200V	8 m	121.5°H; 73.5°V
Leopard Imaging OV580	1280H; 720V	10 m	100°H; 60°V
ZED 2i	1280H; 720V	20 m	110°H; 70°V
ZED X	1920H; 1200V	20 m	110°H; 80V
ZED mini	1280H; 720V	15 m	90°H; 60°V

RADAR SRR TOTAL REQUIREMENTS			
	Speed Resolution	Distance Range	ADAS application
Continental SRR308	0.33 m/s	95 m	LKAS, AEB
Continental SRR520	0.35 m/s	100 m	LKAS, AEB
Texas Instruments AWRL6432	Ultra High	25 m	LKAS, AEB, Traffic Jam
XENSIV™ BGT60ATR24C	High	18 m	LKAS, AEB
Continental SRR600	Ultra High	180 m	LKAS, AEB

SOLUTIONS OVERVIEW:
Analytic Hierarchy Process: Method of decision-makings

The AHP technique is a **ranking process** employed in group decision-making that also enables consistency testing in judgment formation to detect and diminish any **inconsistencies** in opinions or judgments.
The technique prioritises selection criteria and differentiates the **more significant criteria** from the less significant ones. On rows and columns, the **same parameters** are present, so the upper half of the matrix is evaluated.

The **Consistency** is the most important measurement of the results from pairwise comparison in the AHP.
Pairwise comparison is a method to calculate the **weights** for each element in order to perform a comparison of two **advantages**.
The consistency of the AHP will be determined by the **value** of **C.I.**

The consistency ratio (CR) is used to determine the value of probability.
A C.I./R.I. value **below 0.1** is important in the AHP method to **ensure consistency**, enhance decision quality, increase confidence, and facilitate **sensitivity analysis**, all of which contribute to reliable and **robust decision-making**.

λmax value refers to the largest or principal eigen value of the matrix.
λ is calculated for each row as a ratio between weighted sum value and criteria weights, where weighted sum value is the sum of each normalized value of the matrix and the criteria weights are the values on the main diagonal of each row.

$$\lambda = \frac{\text{Weighted } Sum\ Value}{Criteria\ Weights}$$

$$\lambda_{max} = \frac{\lambda_1 + \cdots + \lambda_n}{n}$$

$$C.R. = \frac{C.I.}{R.I.}$$

$$C.I. = \frac{\lambda_{max} - n}{n-1}$$

SOLUTIONS OVERVIEW:

AHP Method for Solid State Lidar: Robosense RS M1

	Range	Range Accuracy	Field Of View	Resolution	Cost	Weather Robustness	Urban ADAS	Highway ADAS	Innovation
Range	1	1	5	3	7	5	5	3	9
Range Accuracy	1	1	7	3	7	3	5	3	9
Field Of View	1/5	1/7	1	1/5	3	1/5	1/3	1/3	1
Resolution	1/3	1/3	5	1	3	1	5	3	5
Cost	1/7	1/7	1/3	1/3	1	1/5	1	1/3	1/3
Weather Robustness	1/5	1/3	5	1	5	1	3	1	3
Urban ADAS	1/5	1/5	3	1/5	1	1/3	1	1/3	5
Highway ADAS	1/3	1/3	3	1/3	3	1	3	1	5
Innovation	1/9	1/9	1	1/5	3	1/3	1/5	1/5	1

λmax	C.I.	C.I. / R.I.
10,0	0,13	0,09

Consistency check [%]
9

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SOLUTIONS OVERVIEW:

AHP Method for Radar 4D: Continental ARS 548

	Range	Range Accuracy	Field Of View	Resolution	Cost	Weather Robustness	Urban ADAS	Highway ADAS	Innovation
Range	1	1	7	3	5	3	9	9	9
Range Accuracy	1	1	7	3	3	3	9	9	9
Field Of View	1/7	1/7	1	1/3	1/3	1/3	3	3	3
Resolution	1/3	1/3	3	1	3	1	7	7	5
Cost	1/5	1/3	3	1/3	1	1/5	3	3	1
Weather Robustness	1/3	1/3	3	1	5	1	5	5	5
Urban ADAS	1/9	1/9	1/3	1/7	1/3	1/5	1	1	3
Highway ADAS	1/9	1/9	1/3	1/7	1/3	1/5	1	1	3
Innovation	1/9	1/9	1/3	1/5	1	1/5	1/3	1/3	1

λmax	C.I.	C.I. / R.I.
9,9	0,11	0,08

Consistency check [%]
8

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SOLUTIONS OVERVIEW:

AHP Method for Camera: NileCam25 CUOAGX GMLS2

	Range	Range Accuracy	Field Of View	Resolution	Cost	Weather Robustness	Urban ADAS	Highway ADAS	Innovation
Range	1	1	3	1/3	7	1/3	1	1/3	3
Range Accuracy	1	1	7	1	9	1/3	3	1	3
Field Of View	1/3	1/7	1	1/5	3	1/7	1/5	1/3	1/3
Resolution	3	1	5	1	5	1/3	3	1	5
Cost	1/7	1/9	1/3	1/5	1	1/9	1/5	1/7	1/5
Weather Robustness	3	3	7	3	9	1	7	3	3
Urban ADAS	1	1/3	5	1/3	5	1/7	1	1/3	3
Highway ADAS	3	1	3	1	7	1/3	3	1	3
Innovation	1/3	1/3	3	1/5	5	1/3	1/3	1/3	1

λmax	C.I.	$\frac{C.I.}{R.I.}$
9,9	0,12	0,08

Consistency check [%]
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SOLUTIONS OVERVIEW:
AHP Method for Stereoscopic Camera: ZED X

	Range	Range Accuracy	Field Of View	Resolution	Cost	Weather Robustness	Urban ADAS	Highway ADAS	Innovation
Range	1	1	1	1/5	5	1/5	5	1/3	3
Range Accuracy	1	1	3	3	9	1	7	1	7
Field Of View	1	1/3	1	1/3	3	1/3	5	1/3	3
Resolution	5	1/3	3	1	7	1	5	1	5
Cost	1/5	1/9	1/3	1/7	1	1/7	1	1/7	1/3
Weather Robustness	5	1	3	1	7	1	9	1	3
Urban ADAS	1/5	1/7	1/5	1/5	1	1/9	1	1/5	3
Highway ADAS	3	1	3	1	7	1	5	1	3
Innovation	1/3	1/7	1/3	1/5	3	1/3	1/3	1/3	1

λmax	C.I.	$\frac{C.I.}{R.I.}$
10,0	0,13	0,09

Consistency check [%]
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SOLUTIONS OVERVIEW:
AHP Method for Radar Short Range: Continental SRR 520

	Range	Range Accuracy	Field Of View	Resolution	Cost	Weather Robustness	Urban ADAS	Highway ADAS	Innovation
Range	1	1/3	1	1/5	7	1/5	5	1/3	3
Range Accuracy	3	1	3	1	7	1	7	1	7
Field Of View	1	1/3	1	1/7	5	1/5	3	1/3	3
Resolution	5	1	7	1	9	1	7	3	7
Cost	1/7	1/7	1/5	1/9	1	1/9	1/5	1/5	1/3
Weather Robustness	5	1	5	1	9	1	5	3	3
Urban ADAS	1/5	1/7	1/3	1/7	5	1/5	1	1/3	3
Highway ADAS	3	1	3	1/3	5	1/3	3	1	5
Innovation	1/3	1/7	1/3	1/7	3	1/3	1/3	1/5	1

λmax	C.I.	$\frac{C.I.}{R.I.}$
10,1	0,14	0,09

Consistency check [%]
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SOLUTIONS OVERVIEW:
AHP Method for Kit: Solution 1

	Range	Range Accuracy	Field Of View	Resolution	Cost	Weather Robustness	Urban ADAS	Highway ADAS	Innovation
Range	1	1	5	3	7	1	5	5	7
Range Accuracy	1	1	7	3	7	1/3	5	5	9
Field Of View	1/5	1/7	1	1/3	3	1/5	3	1	1
Resolution	1/3	1/3	3	1	5	1/3	5	3	5
Cost	1/7	1/7	1/3	1/5	1	1/5	1	1/3	1/3
Weather Robustness	1	3	5	3	5	1	7	7	9
Urban ADAS	1/5	1/5	1/3	1/5	1	1/7	1	1	3
Highway ADAS	1/5	1/5	1	1/3	3	1/7	1	1	3
Innovation	1/7	1/9	1	1/5	3	1/9	1/3	1/3	1

λmax	C.I.	$\frac{C.I.}{R.I.}$
9,9	0,11	0,08

Consistency check [%]
8

Solution 1, consisting of: **CONTINENTAL ARS 548 RDI, ZED X, CONTINENTAL SRR520, NileCam25 CUXVR GMLS2**, presents the best Consistency Check compared to the other solution analyzed.

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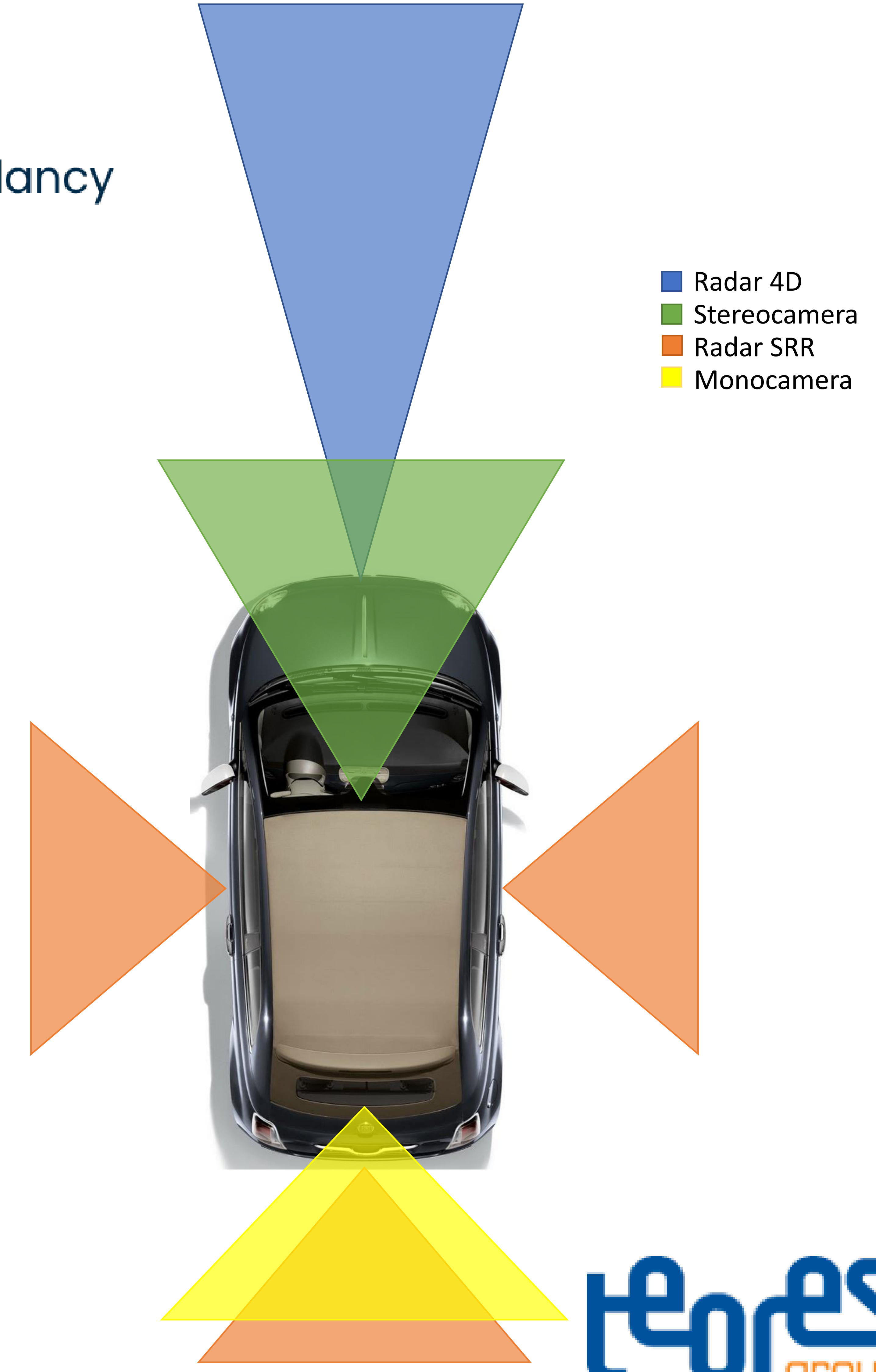
NEW ADAS Architecture – Solution 1

Solution 1: Kit composed by 4D Radar, SR Radars and mono/stereo camera redundancy

SENSOR	Type	Max Range	Range Accuracy	FoV	Resolution	Cost	Quantity
CONTINENTAL ARS 548 RDI	Radar 4D	300 m	± 0.15 m	± 60°	0.10 m/s	4000 €	1
ZED X / Leopard AR0234CS	Smart Stereo / Stereocamera	20 m / 8 m	-	110°H/80°V 121.5°H/73.5°V	1920Hx1200V	550 € / 370 €	1
CONTINENTAL SRR520	Radar SRR	100 m	± 0.22 m ± 0.5 m	± 90°	0.35 m/s	50 €	3
NileCam25 CUOAGX GMLS2 / CONTINENTAL MFC527	Monocamera / Smart Mono	-	-	104.6°H/61.6°V 110°H/70°V	1920Hx1200V 1280Hx960V	505 € / 550 €	1



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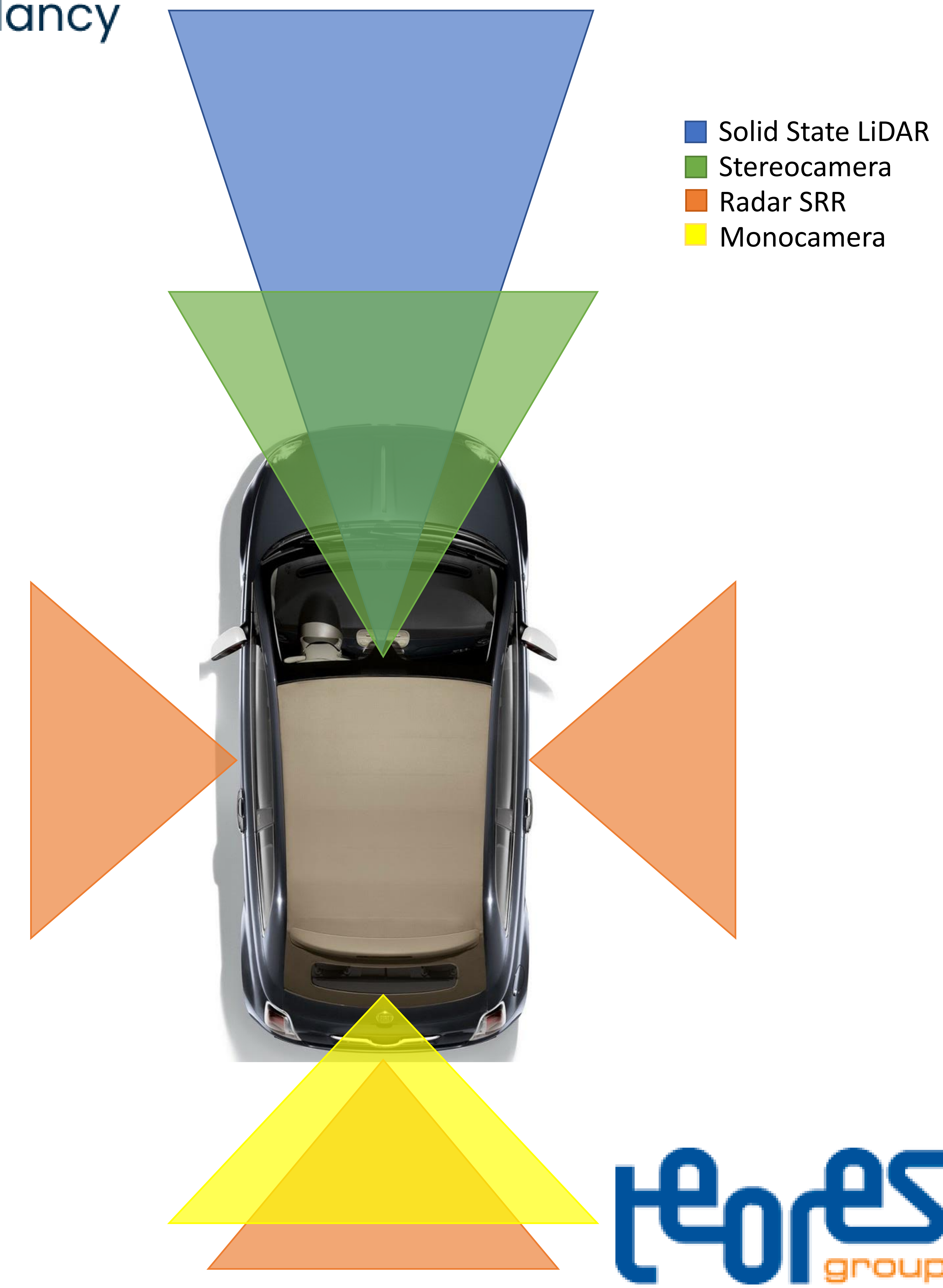
NEW ADAS Architecture – Solution 2

Solution 2: Kit composed by 3D LiDAR, SR Radars and mono/stereo camera redundancy

SENSOR	Type	Max Range	Range Accuracy	FoV	Resolution	Cost	Quantity
ROBOSENSE M1	Solid State LiDAR	200 m	-	120°H 25.1°V	0.2°H 0.2 °V	5000 €	1
ZED X	Smart Stereocamera	20 m	-	110°H/80°V	1920Hx1200V	550 €	1
CONTINENTAL SRR520	Radar SRR	100 m	± 0.22 m ± 0.5 m	± 90°	0.35 m/s	50 €	3
NileCam25 CUOAGX GMLS2	Monocamera	-	-	104.6°H/61.6°V	1920Hx1200V	505 €	1



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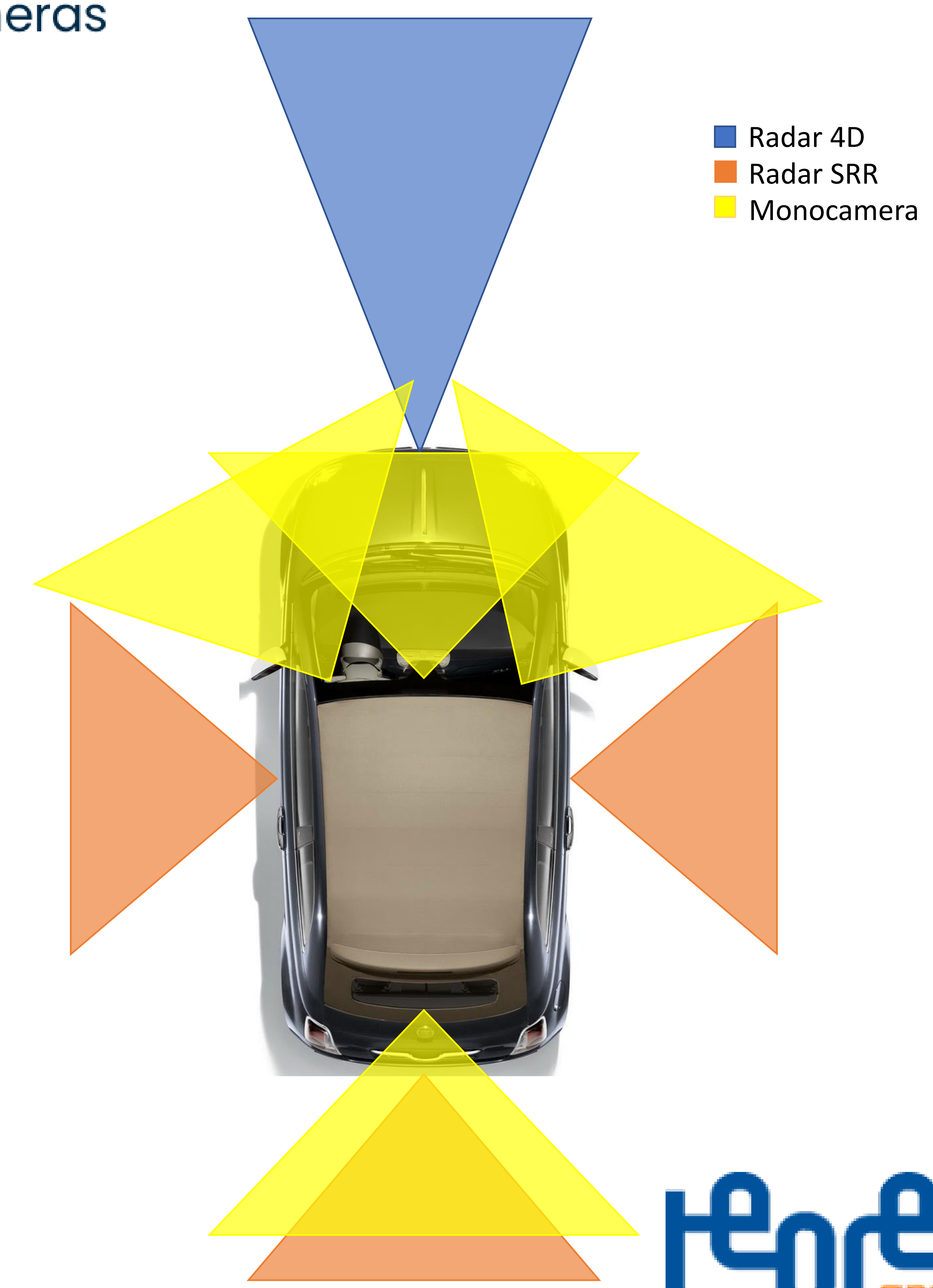
NEW ADAS Architecture – Solution 3

Solution 3: Kit composed by 4D Radar, SR Radars and combination of mono cameras

SENSOR	Type	Max Range	Range Accuracy	FoV	Resolution	Cost	Quantity
CONTINENTAL ARS 548 RDI	Radar 4D	300 m	± 0.15 m	± 60°	0.10 m/s	4000 €	1
CONTINENTAL SRR520	Radar SRR	100 m	± 0.22 m ± 0.5 m	± 90°	0.35 m/s	50 €	3
NileCam25 CUOAGX GMLS2	Monocamera	-	-	104.6°H/61.6°V	1920Hx1200V	505 €	4



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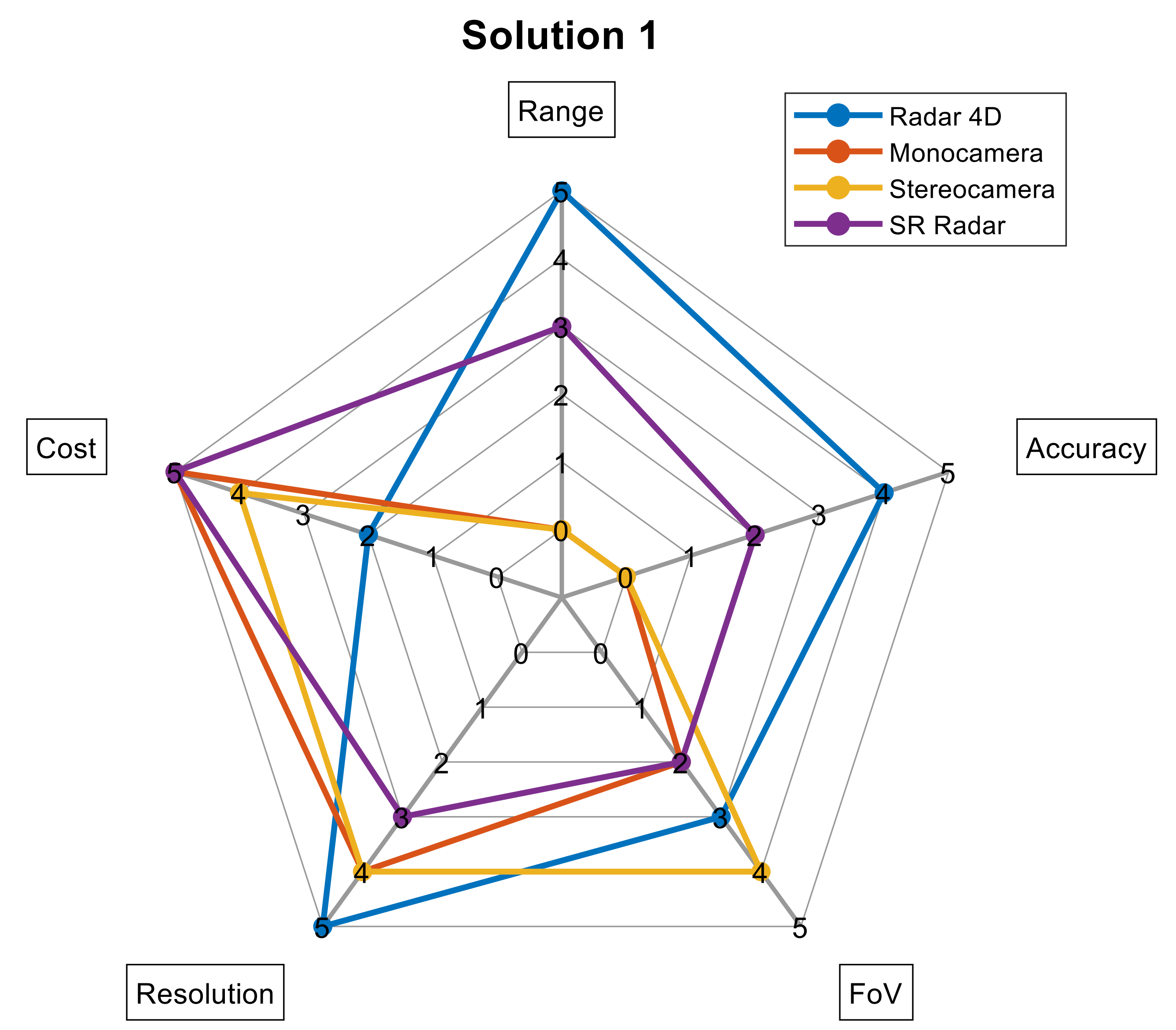
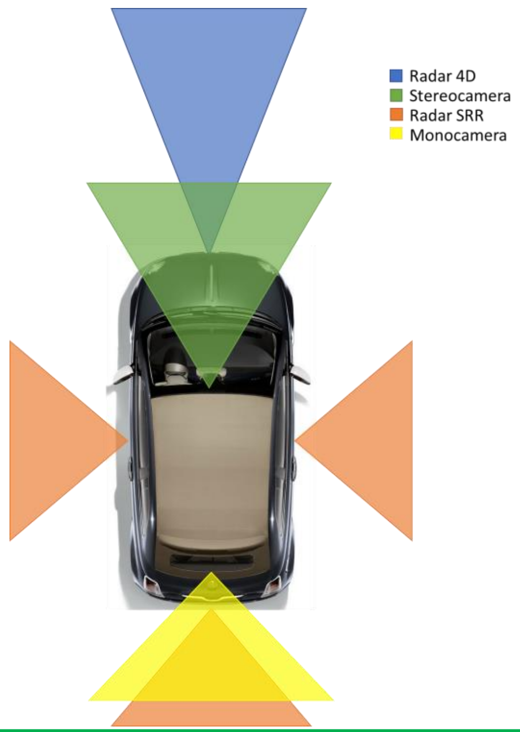
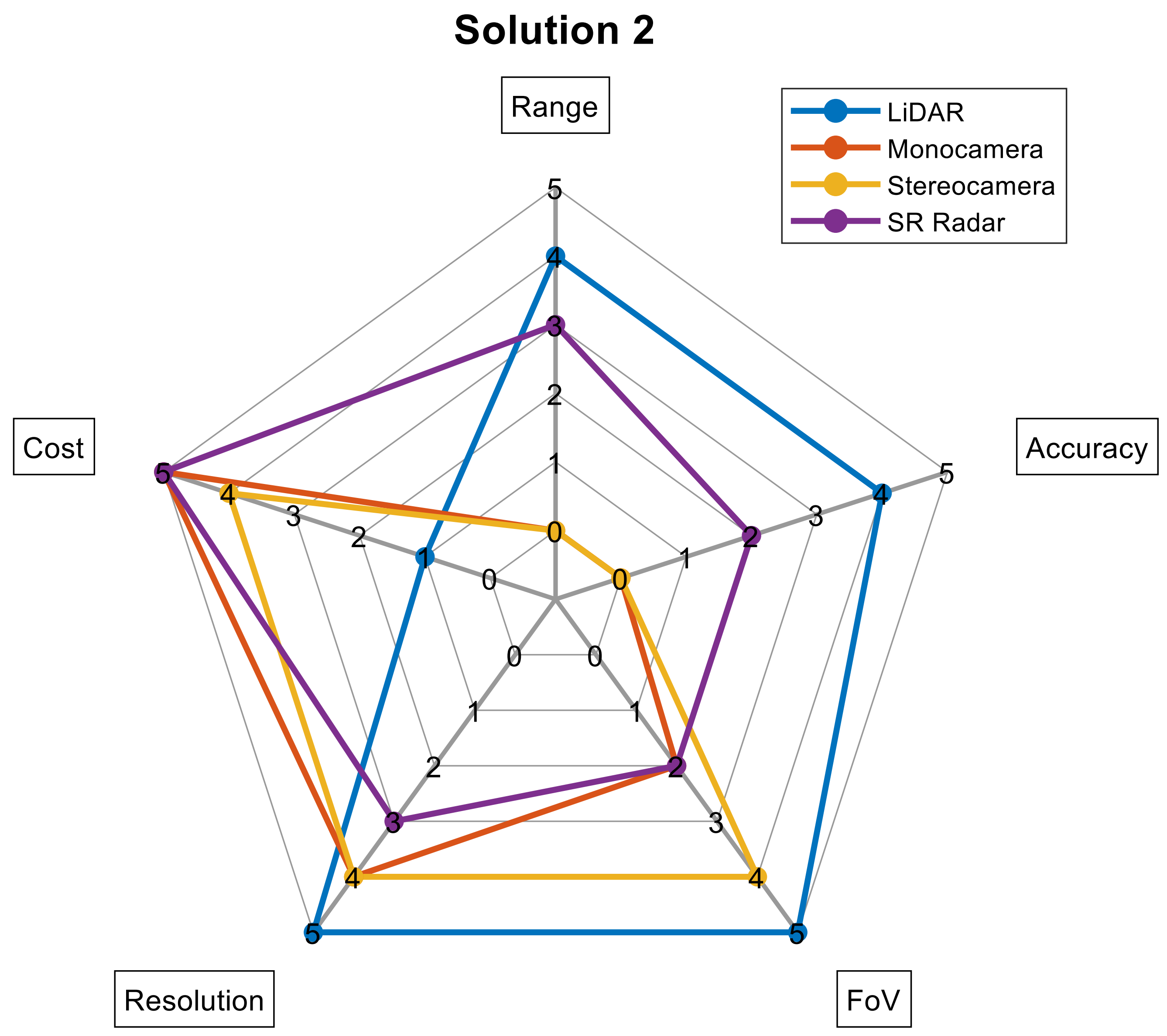
NEW ADAS Architecture – Comparison

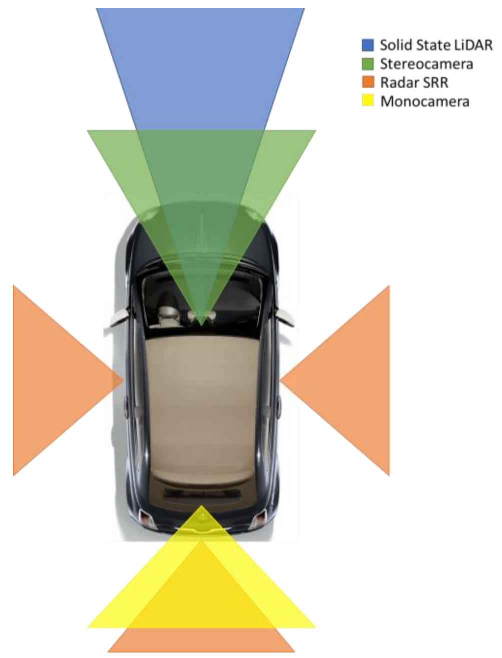
Comparison: Sensors' Kits characteristics comparison for BOM definition



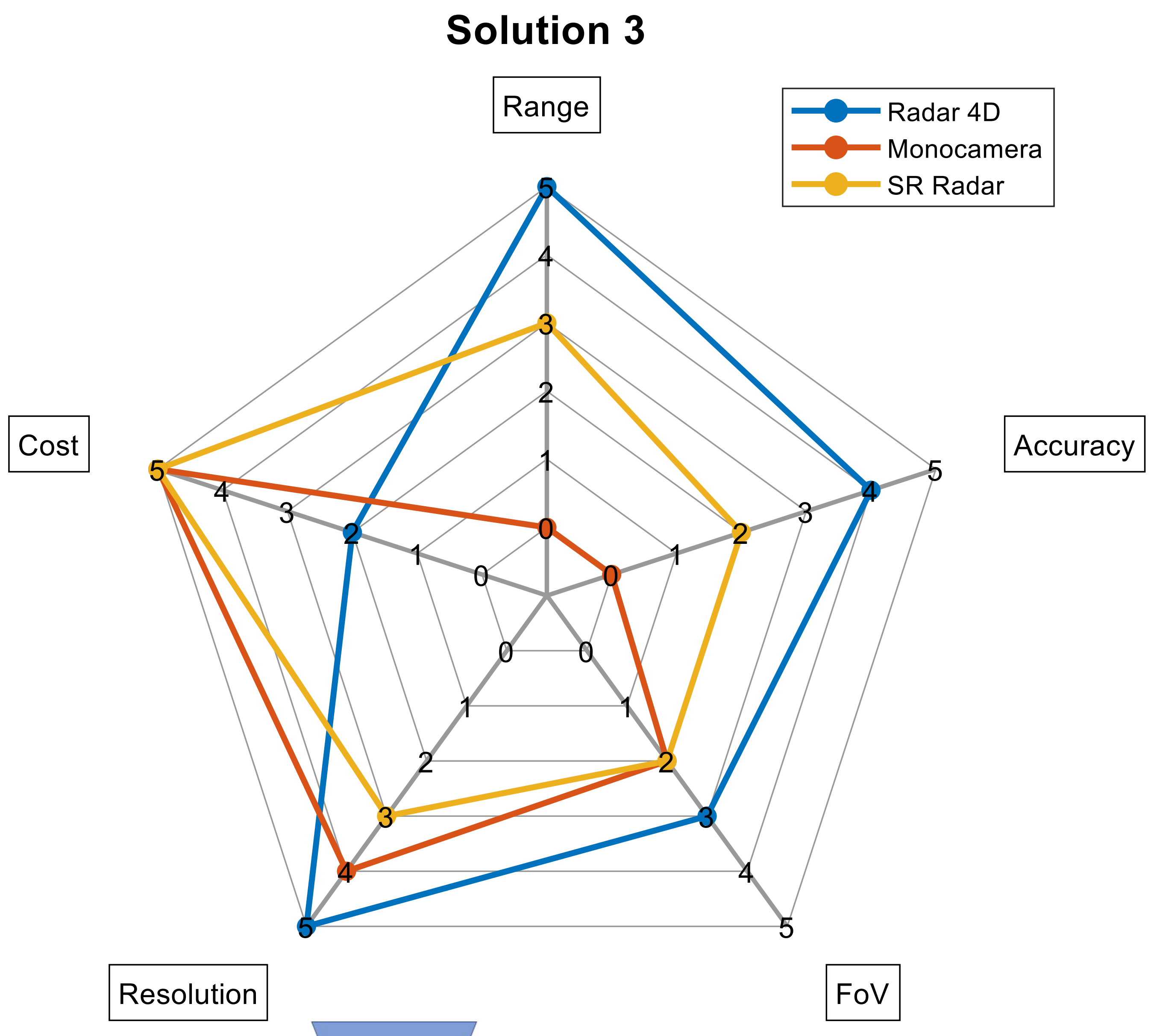


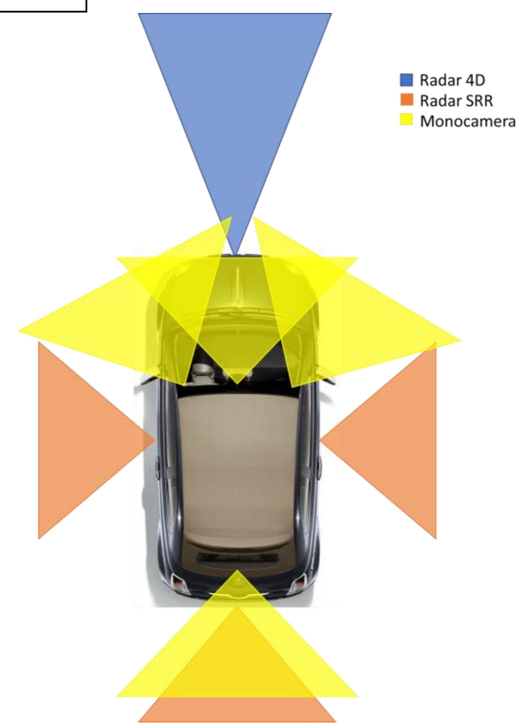
Range = 4
Accuracy = 3
FoV = 2.75
Resolution = 4
Cost = 4





Range = 3.5
Accuracy = 3
FoV = 3.25
Resolution = 4
Cost = 3.75





Range = 4
Accuracy = 3
FoV = 1.75
Resolution = 4
Cost = 4

NEW ADAS Architecture – BOM

BOM: Components considered for purchase with commercial costs and redundancies

Solution 1 BOM				
Sensor type	**Sensor model**	**Cost [€]**	**Quantity**	**Subtotal [€]**
Radar 4D	CONTINENTAL ARS 548 RDI	4000	1	4000
Radar SR	CONTINENTAL SRR520	50	3	150
Stereocamera	Leopard AR0234CS	370	1	370
Smart Stereo	ZED X	550	1	550
Monocamera	NileCam25 CUOAGX GMLS2	505	3	1515
Smart Mono	CONTINENTAL MFC527	550	1	550
			Total	7135 €

Solution 1 extended kit BOM				
Sensor type	**Sensor model**	**Cost [€]**	**Quantity**	**Subtotal [€]**
Radar 4D	TBD	~ 4000 (TBC)	1	4000
Radar LR	TBD	~ 300	1	300
LiDAR	HESAI AT128	~ 3000 (TBC)	1	3000
			Total	~ 7300 €

The Solution 1 BOM takes into account the most promising kit composed by **4D Radar, Stereocamera, Monocamera and SR Radar.**
In the list both smart and standard cameras have been considered to assess the impact on costs.

The extended kit is evaluated for redundancy on the main sensor for long range detection and could give added value to the analysis, in particular:

- The use of **another model of 4D Radar** to use as benchmark for Continental ARS 548 RDI performance. The model and supplier have to be defined.
- The use of a **Long Range (LR) Radar** instead of 4D one to explore the difference in performance among the older and the new generation of products. Also in this case model and supplier have to be defined.

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Thank you

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