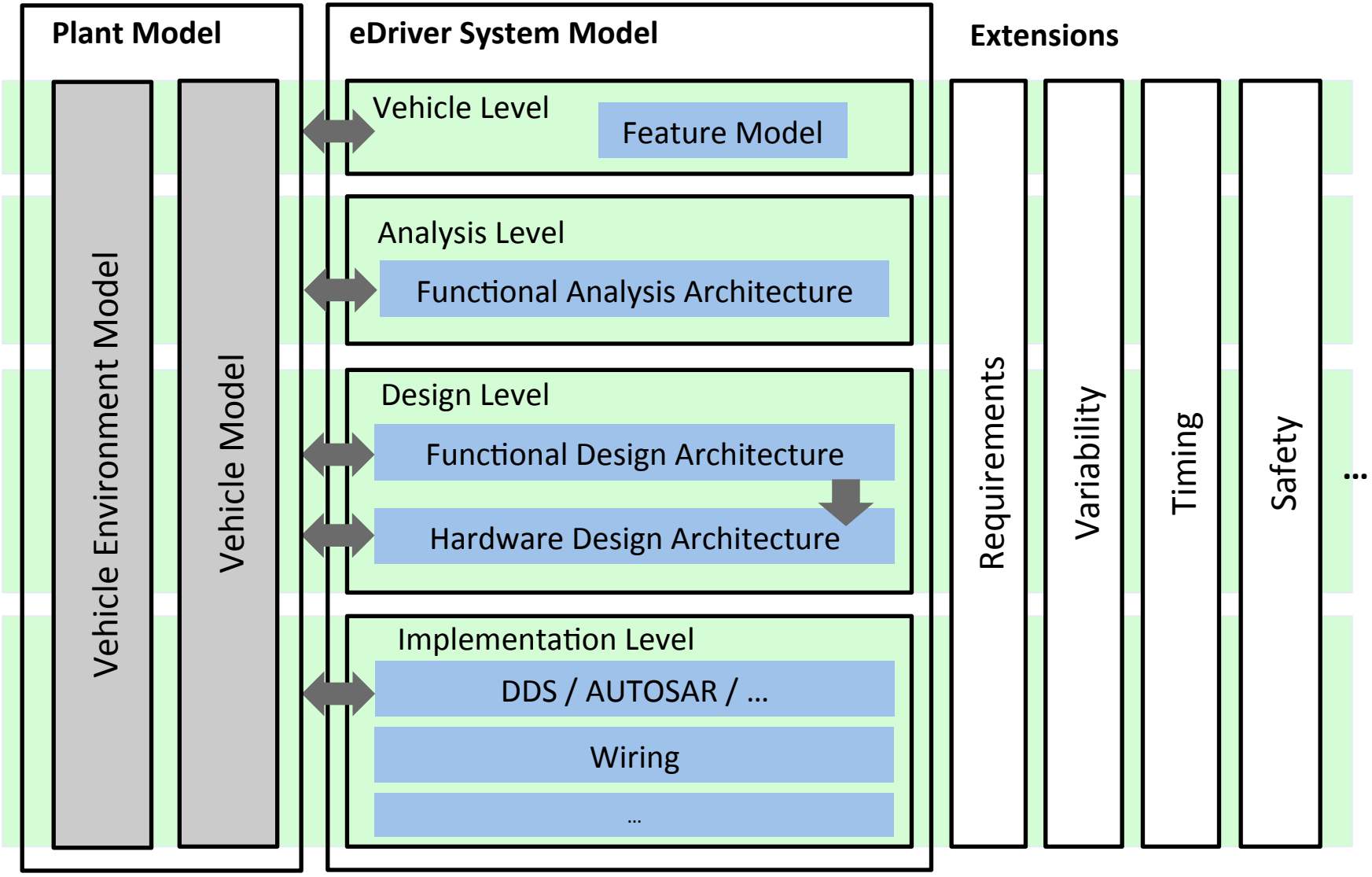
Model-Based Assurance Challenges for Self-Driving Cars

Krzysztof Czarnecki
Electrical and Computer Engineering Department

EAST-ADL Architectural Model



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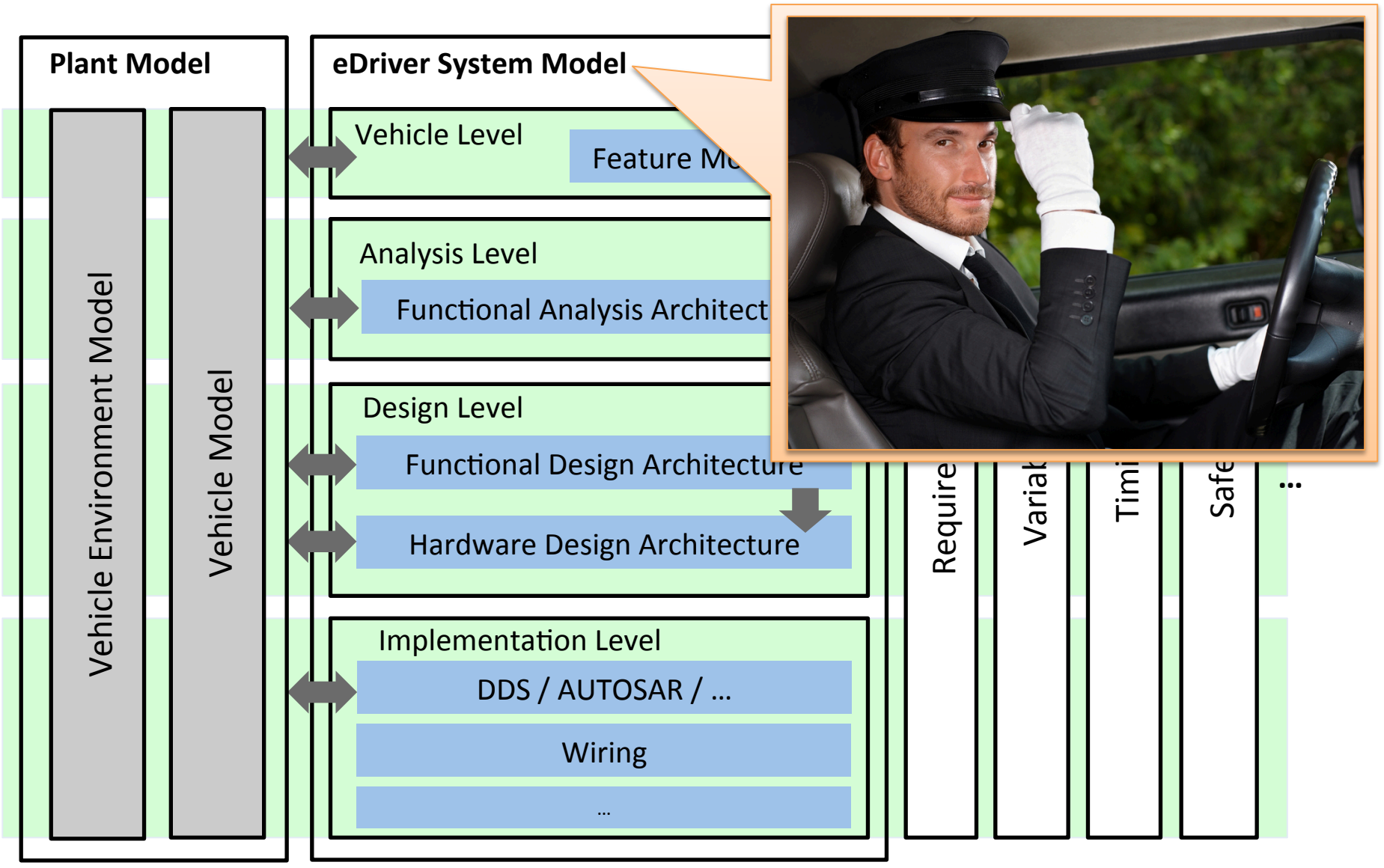

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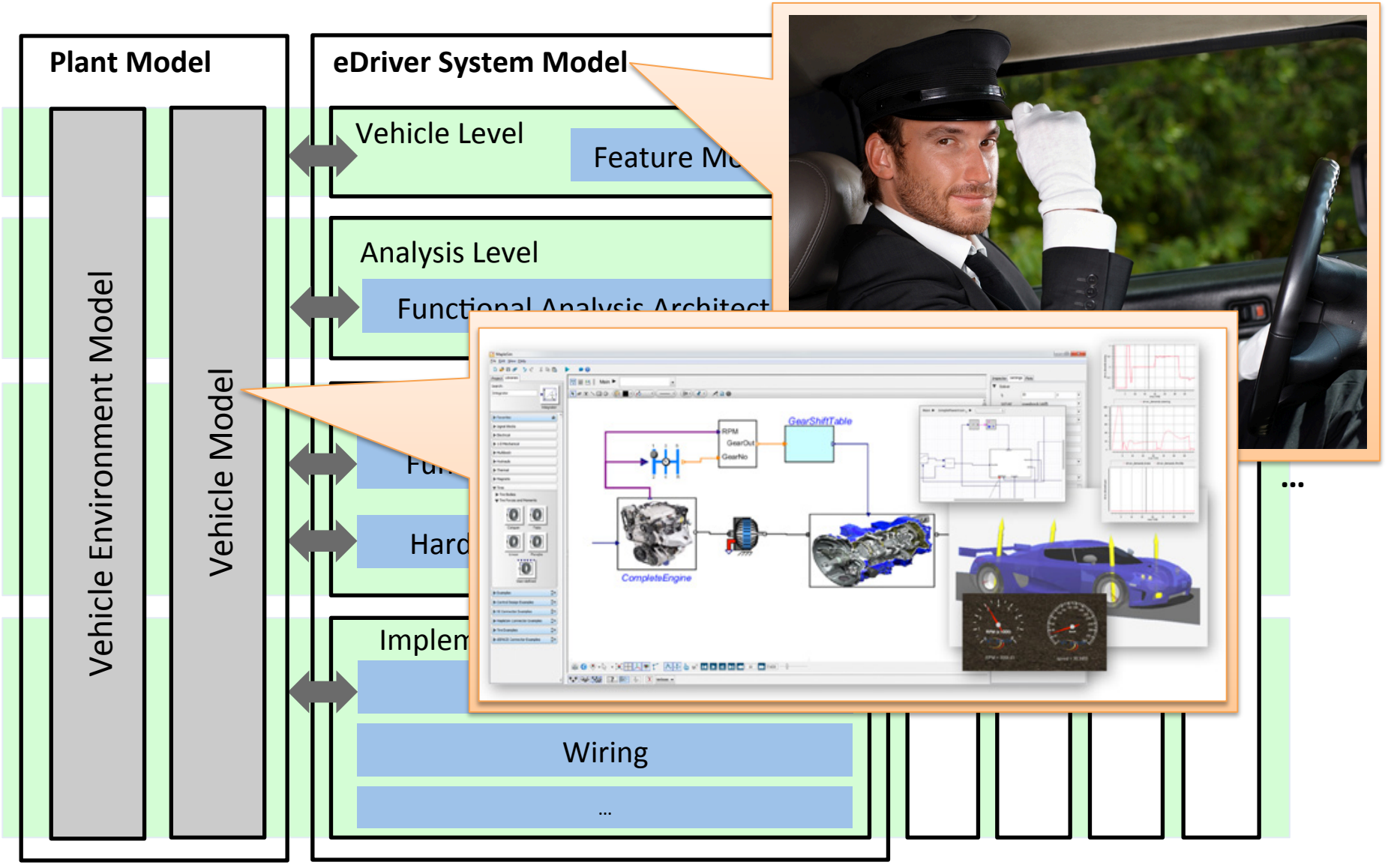

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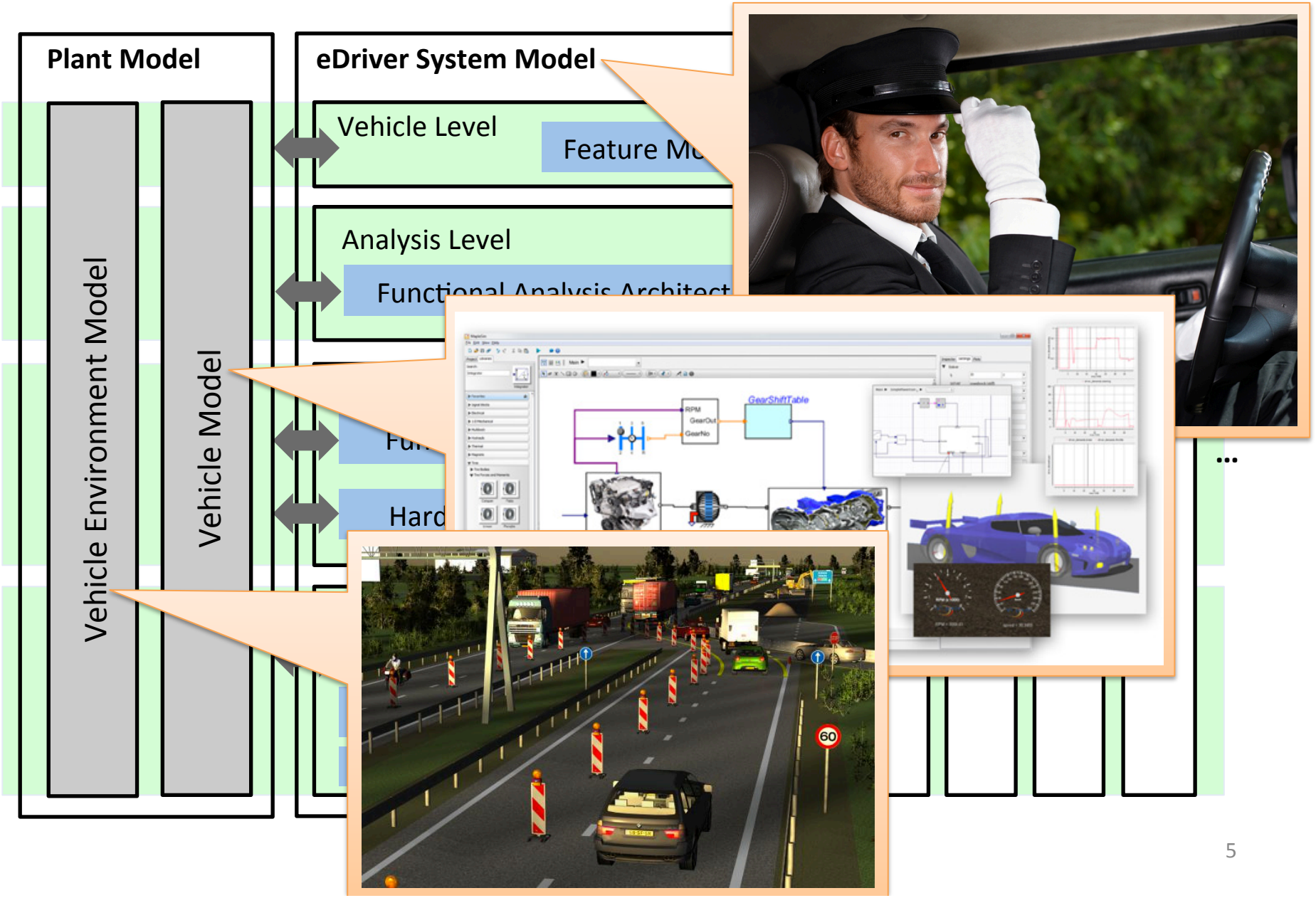

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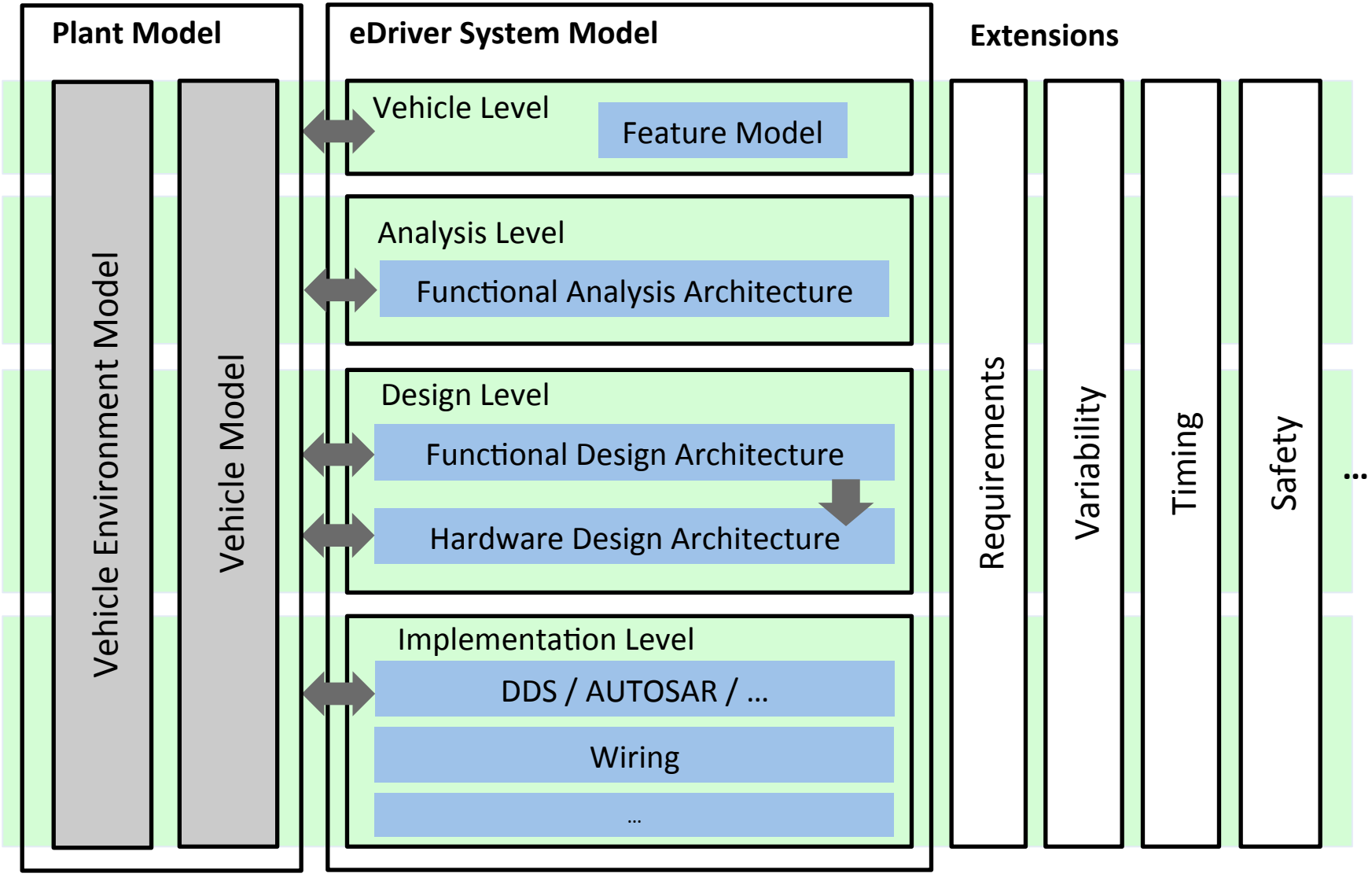

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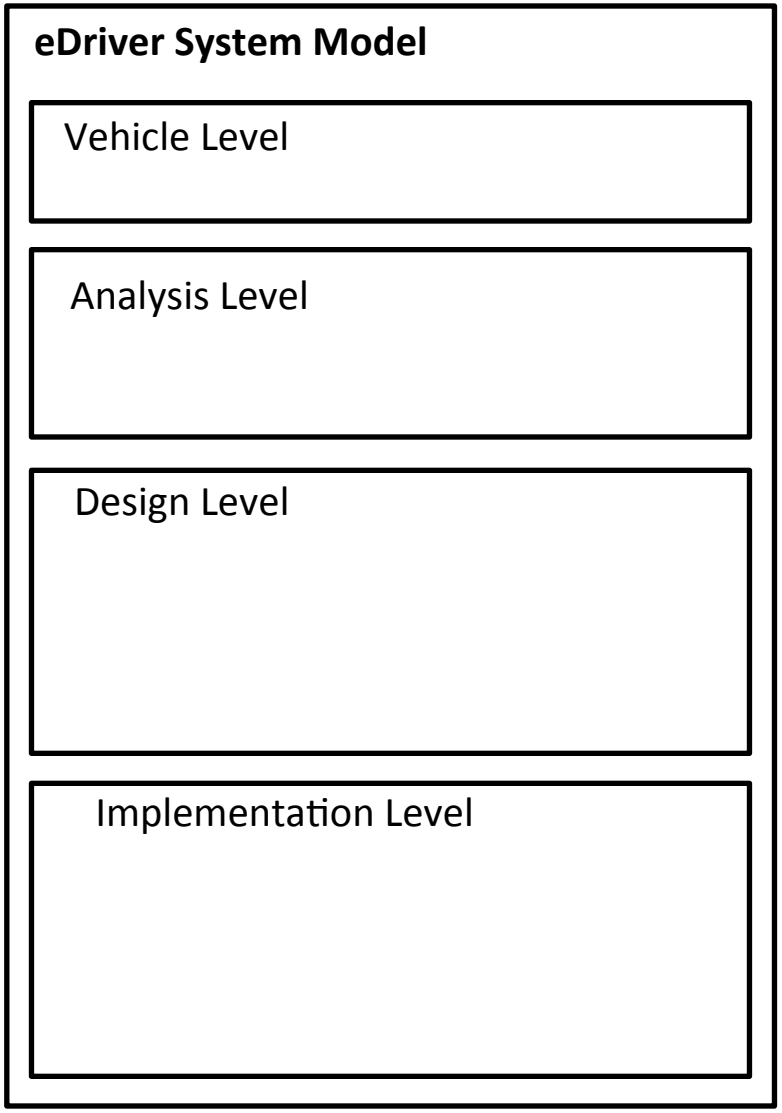

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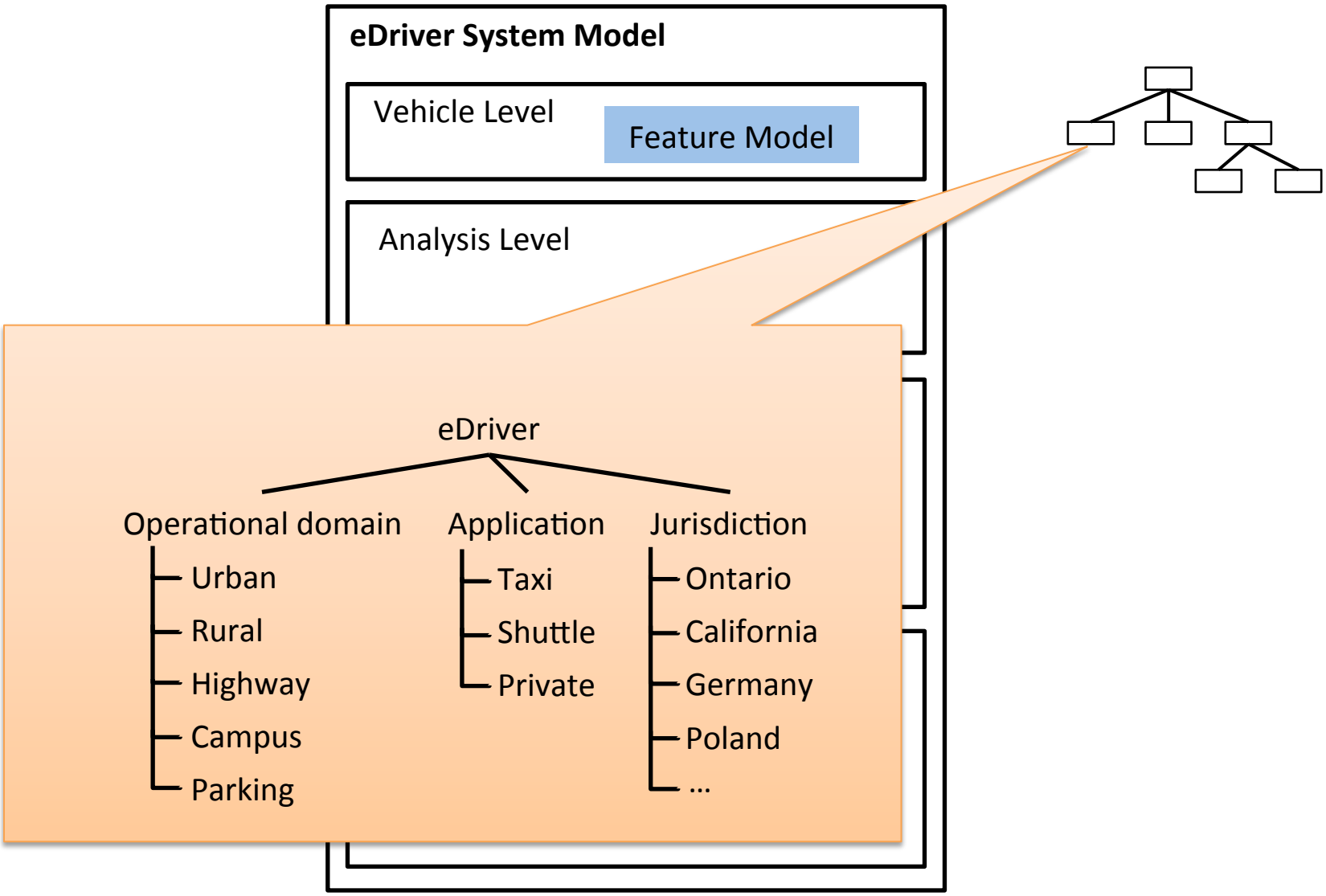

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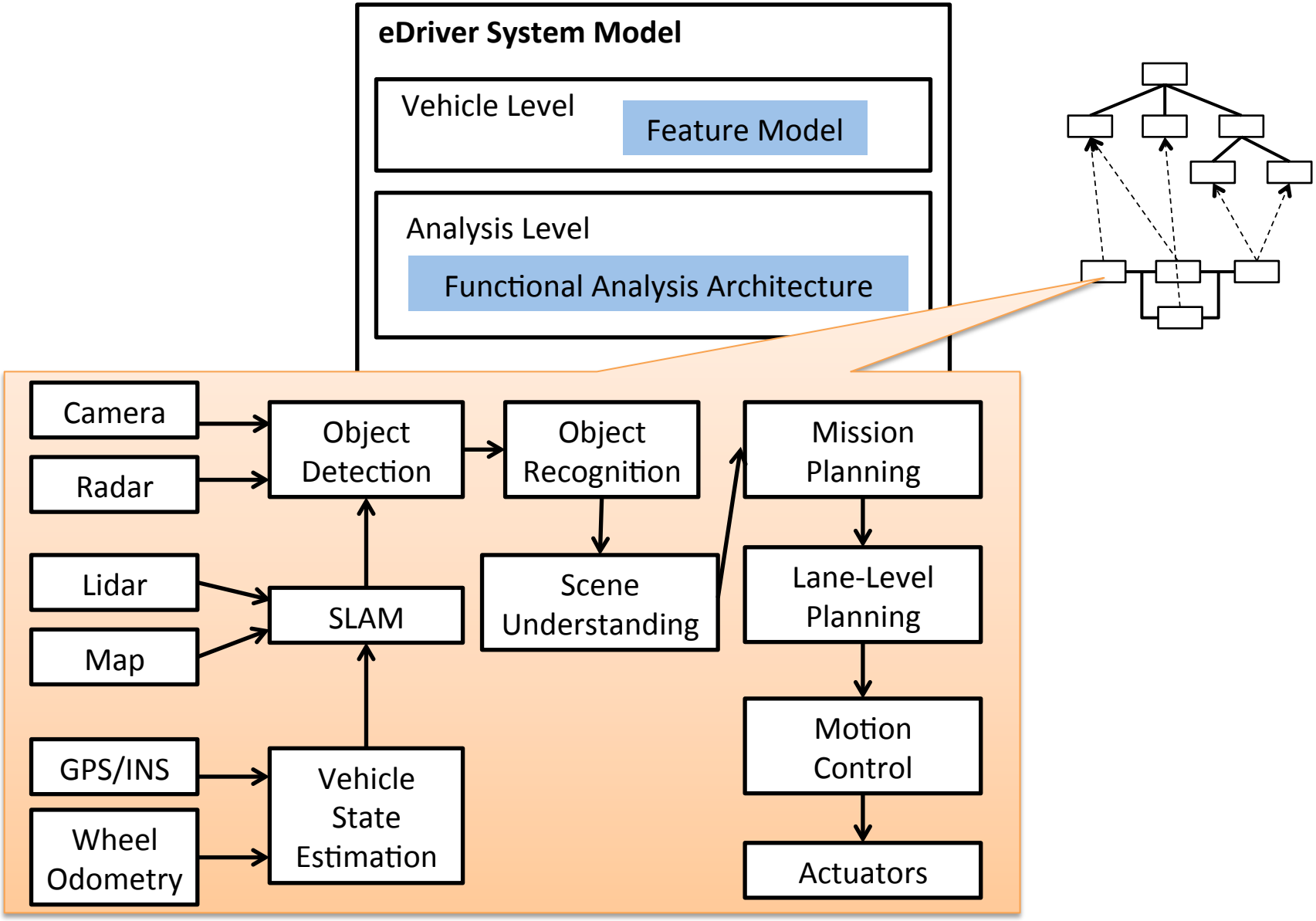

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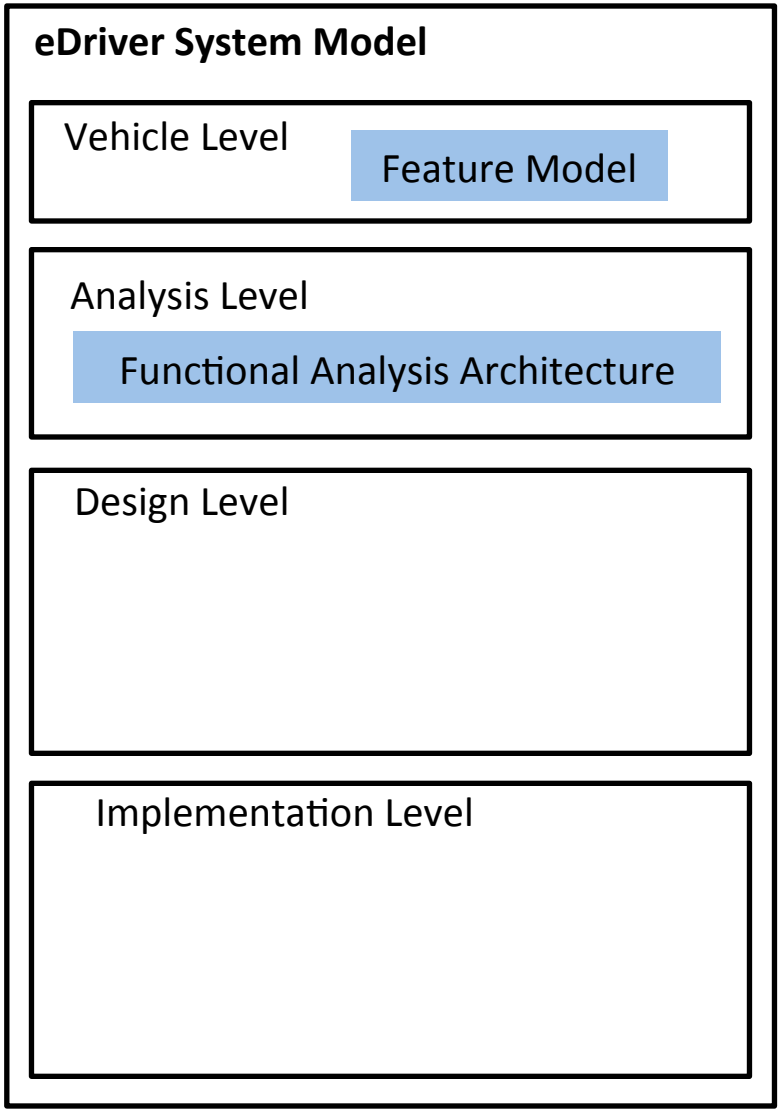

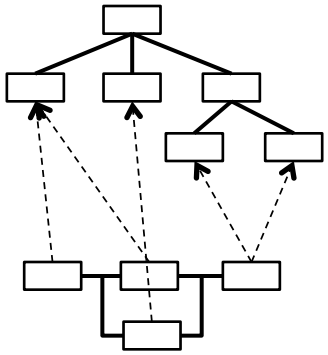

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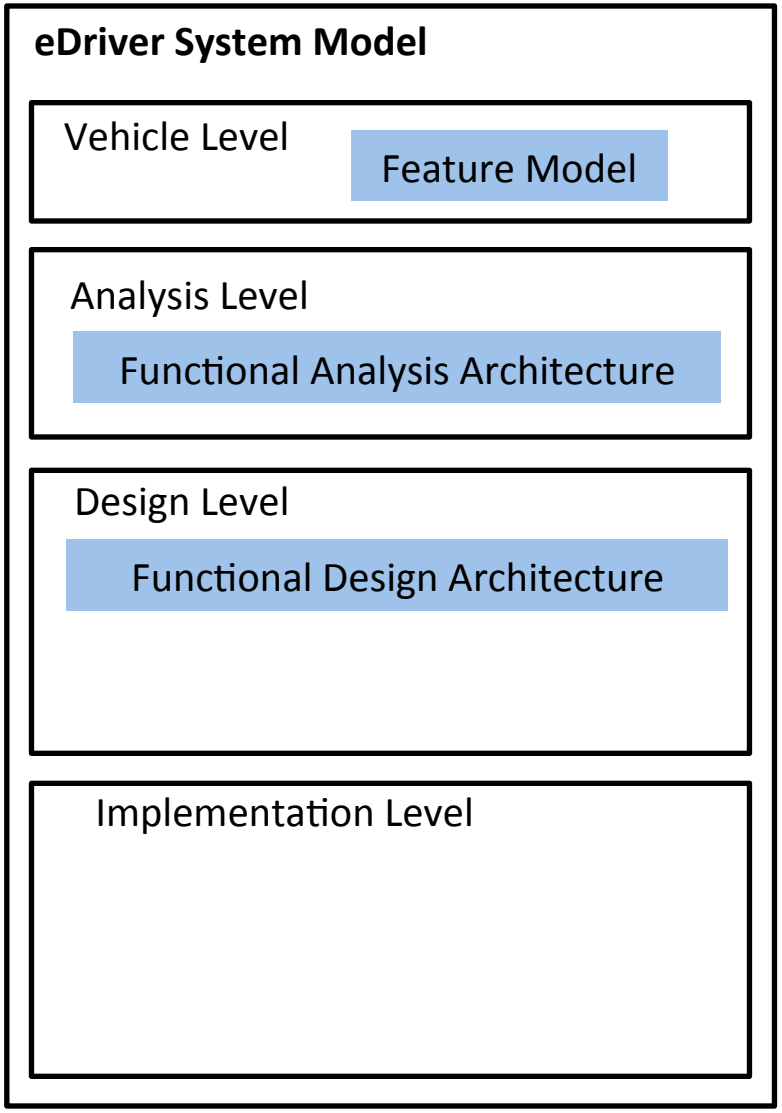

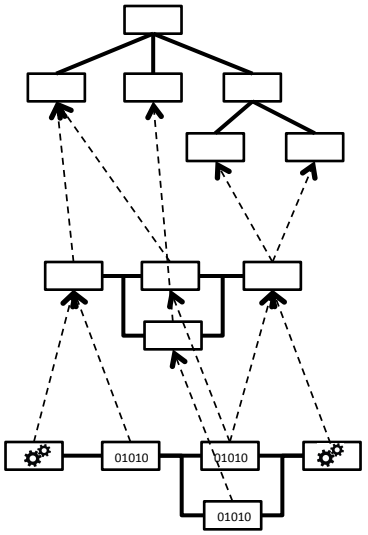

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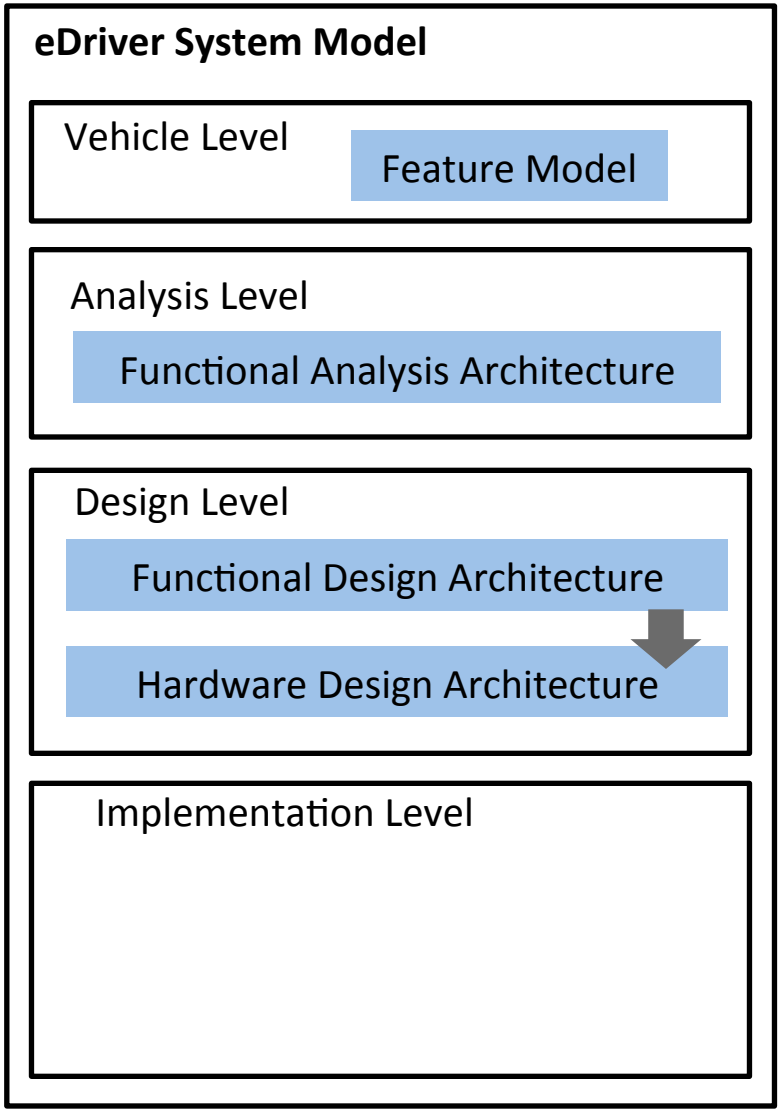
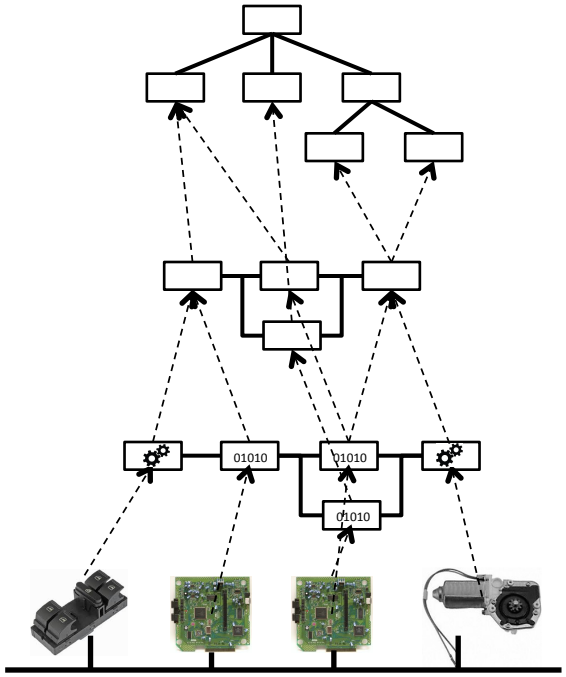
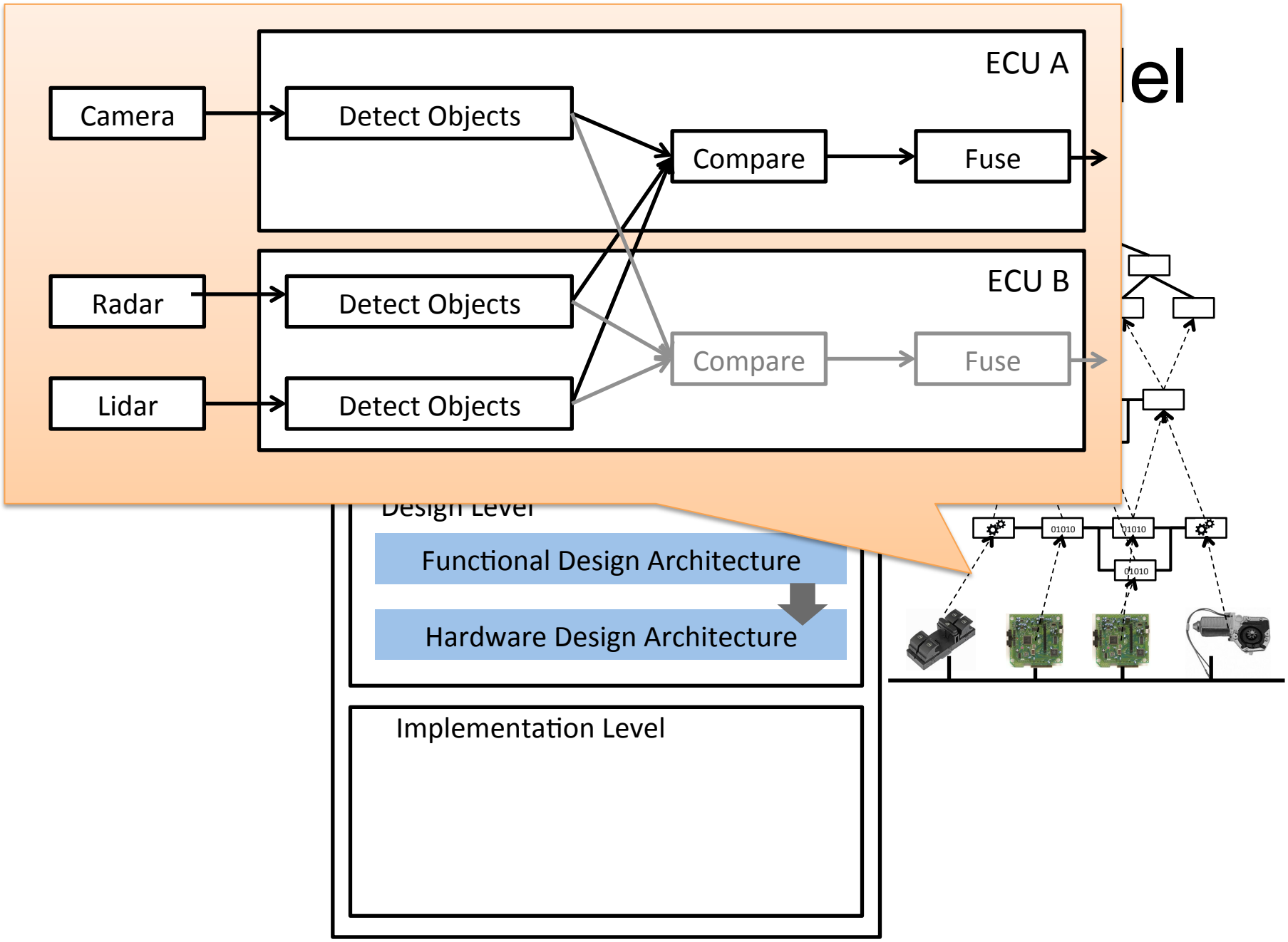
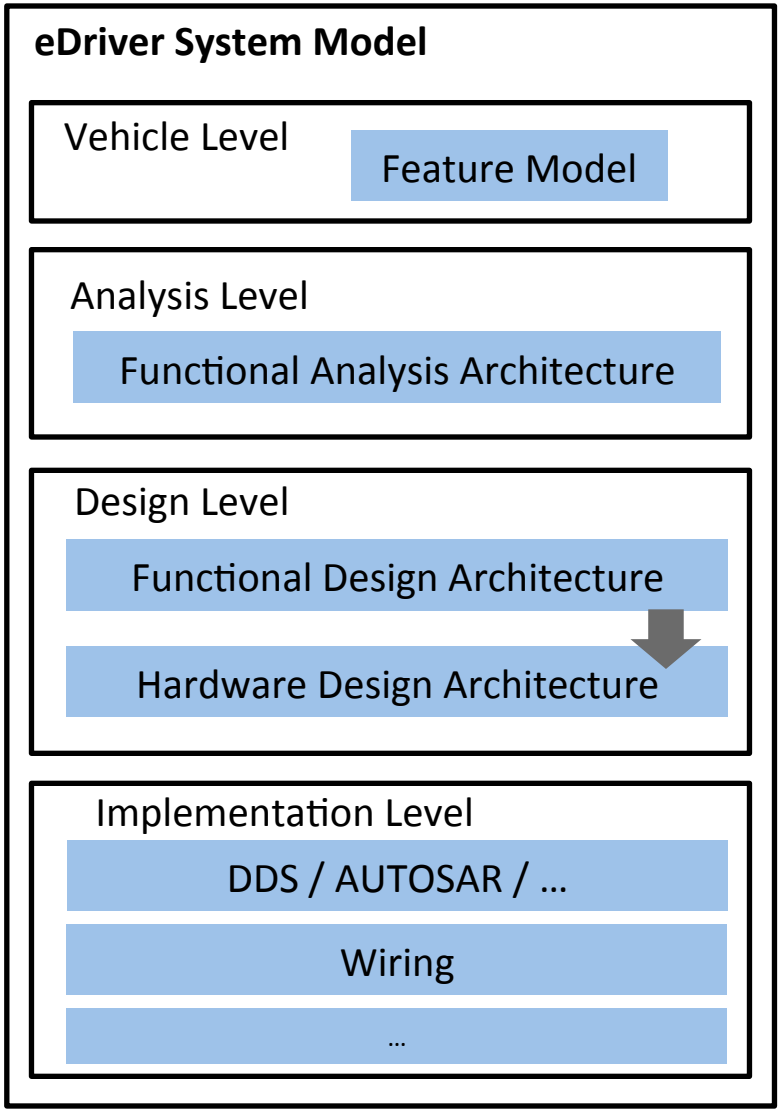
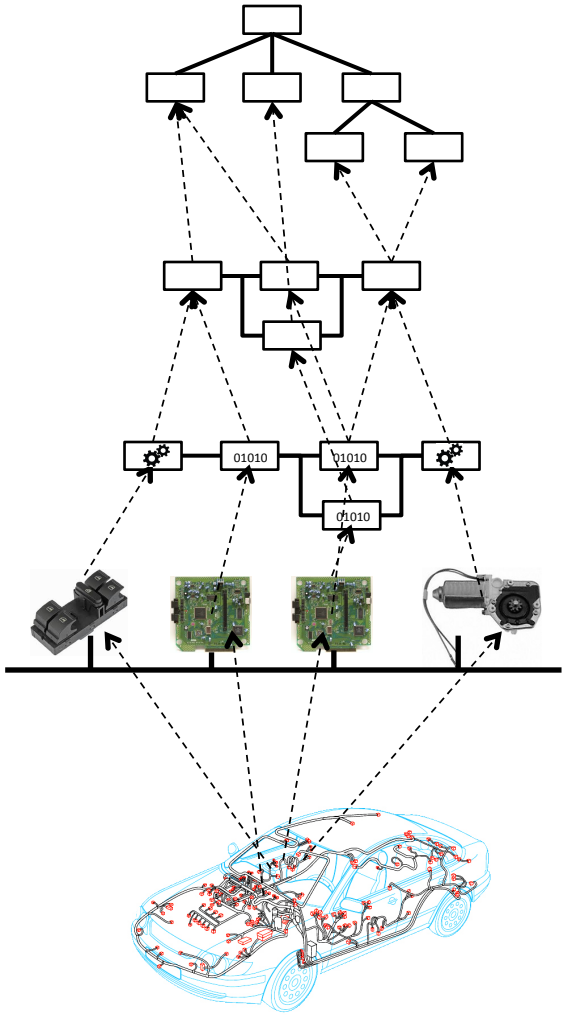





ECU A
Camera
Detect Objects
Compare
Fuse
ECU B
Radar
Detect Objects
Compare
Fuse
Lidar
Detect Objects
Functional Design Architecture
Hardware Design Architecture
Implementation Level
01010
01010
01010

EAST-ADL Architectural Model





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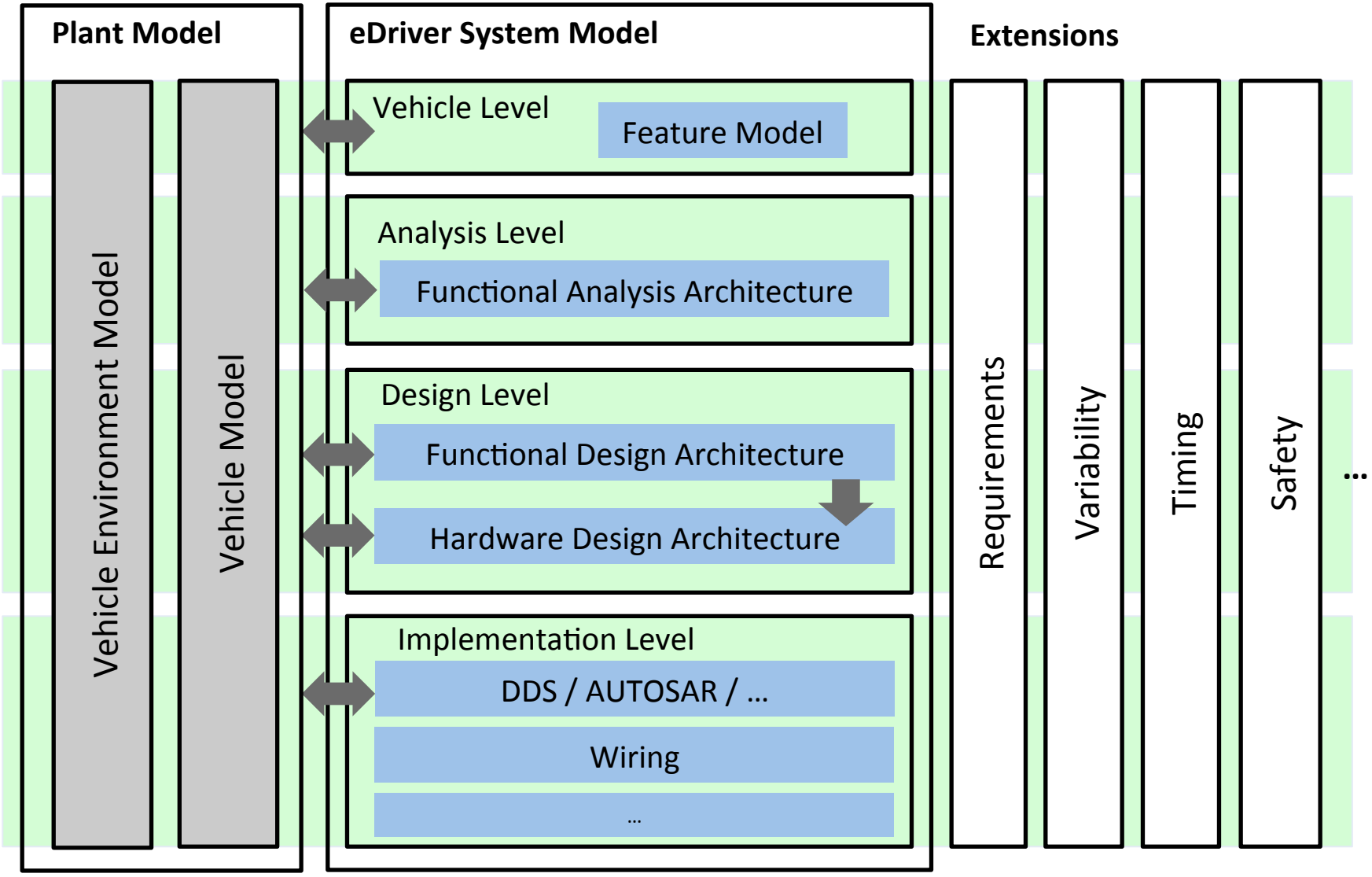
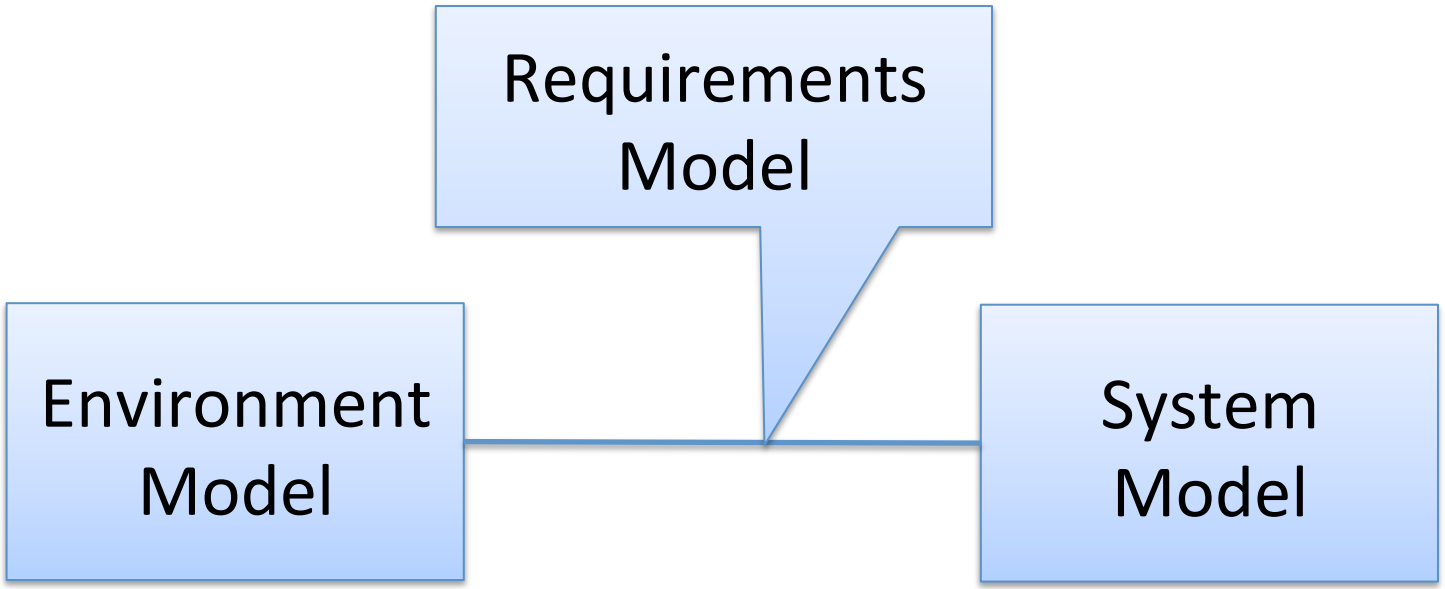
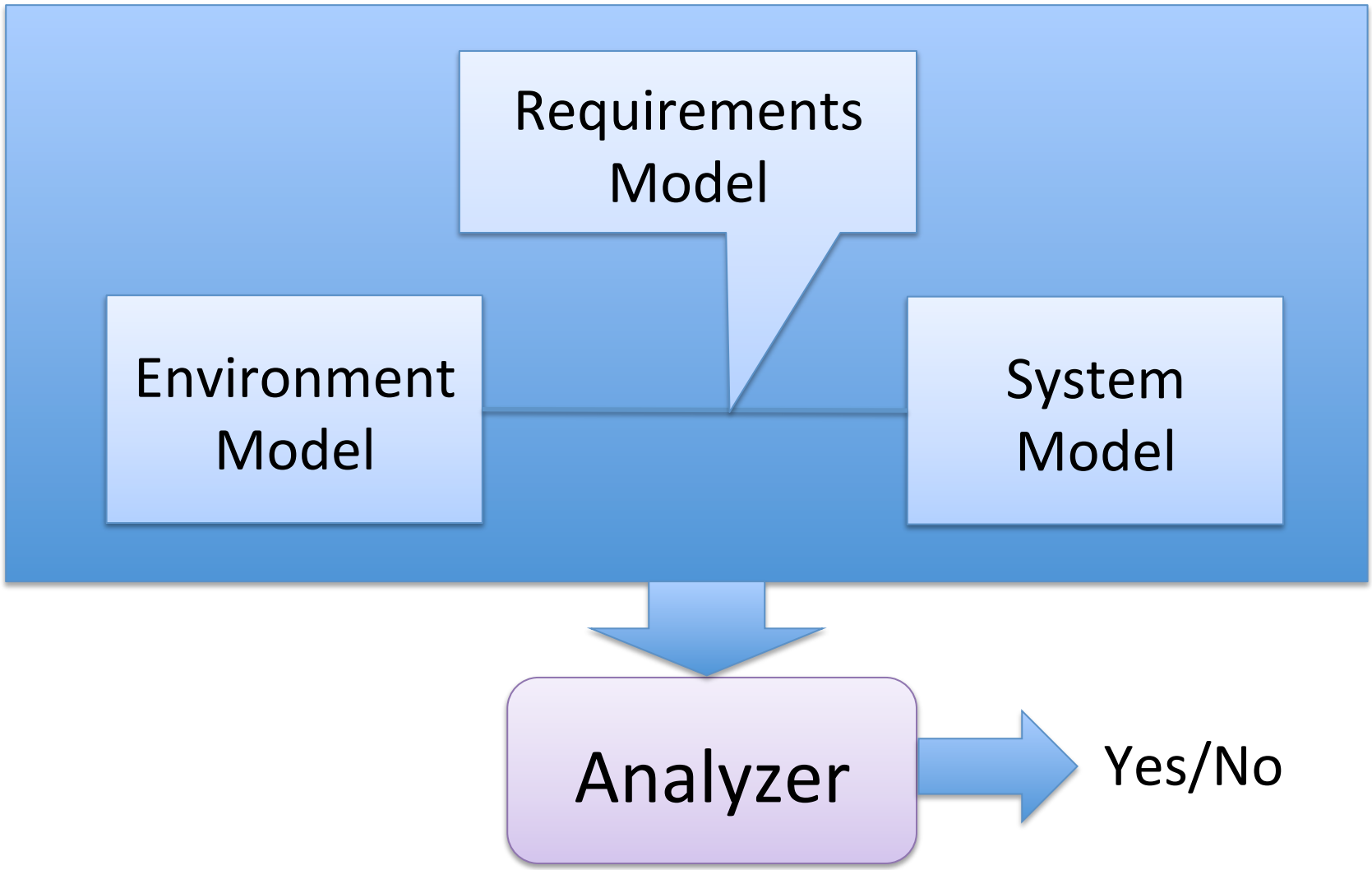


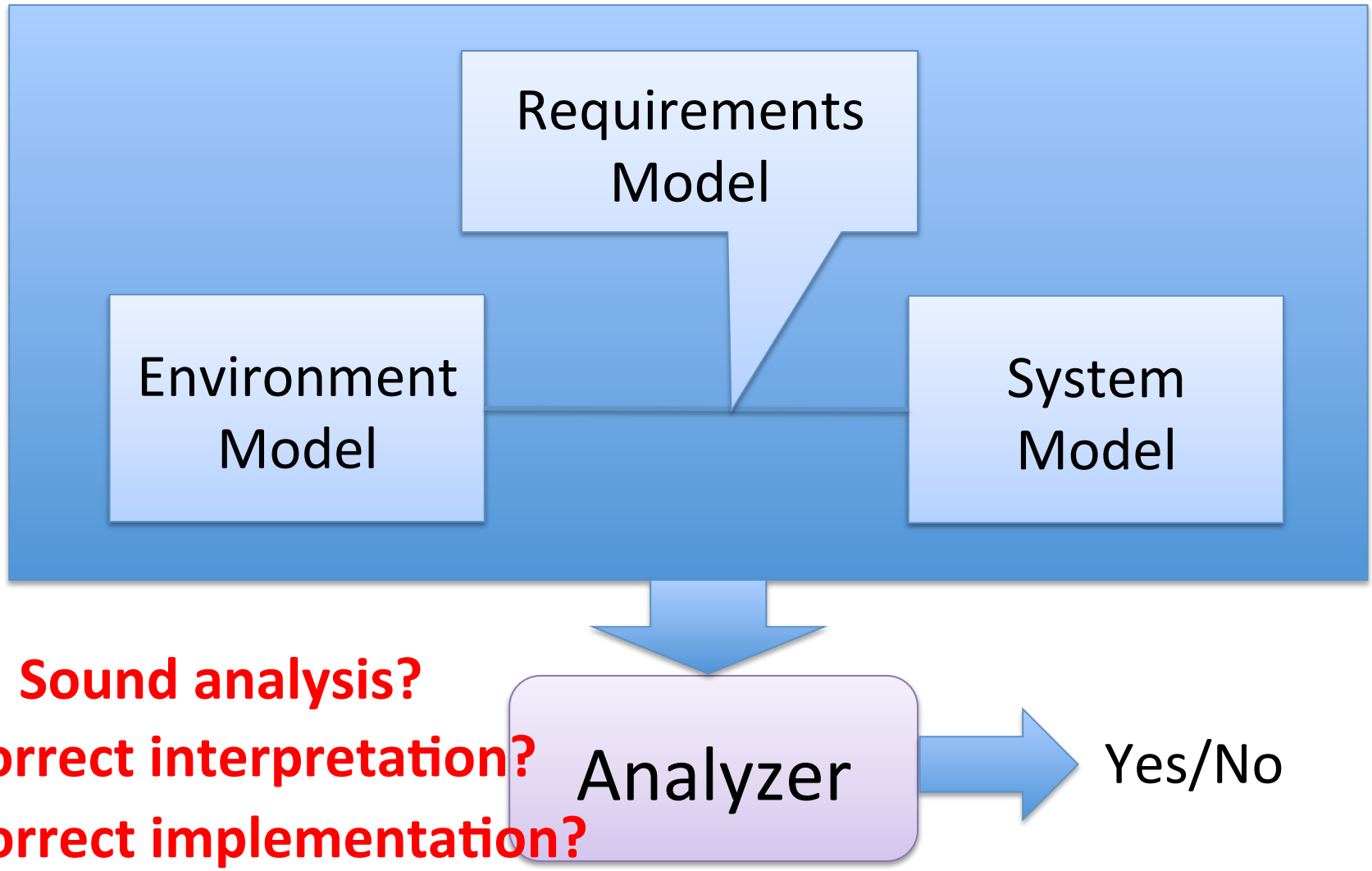
Model-Based Assurance



Model-Based Assurance



Model-Based Assurance

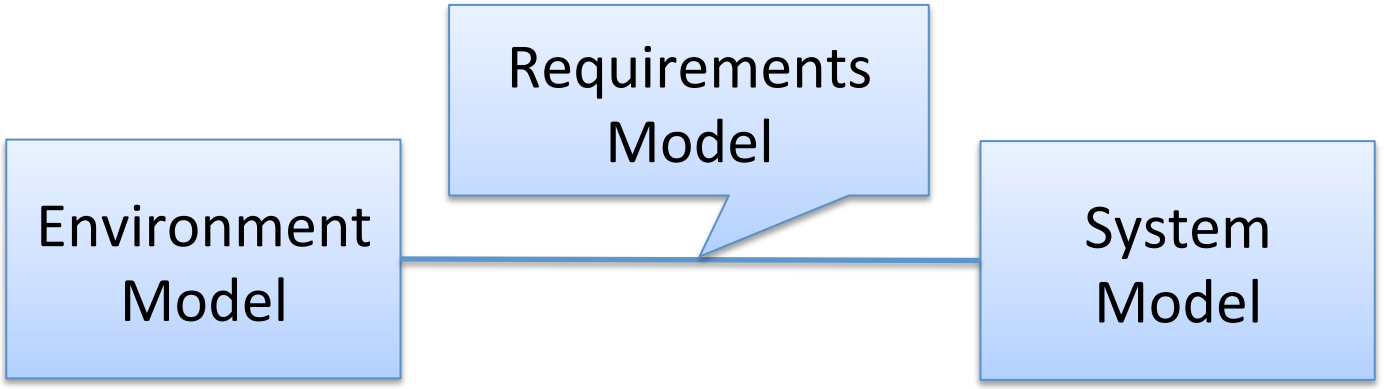


Sound analysis?

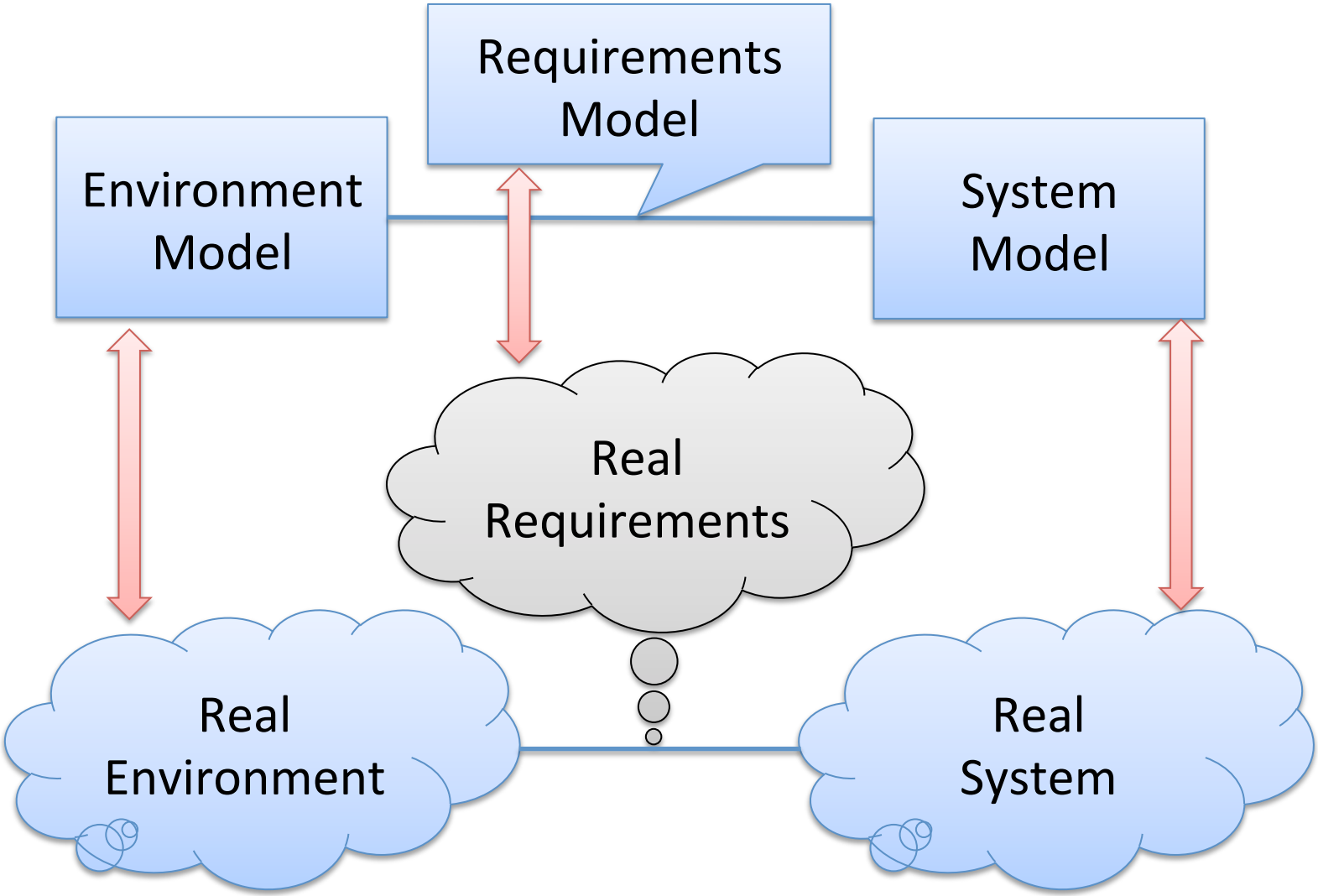
Correct interpretation?

Correct implementation?

Model-Based Assurance



Model-Based Assurance



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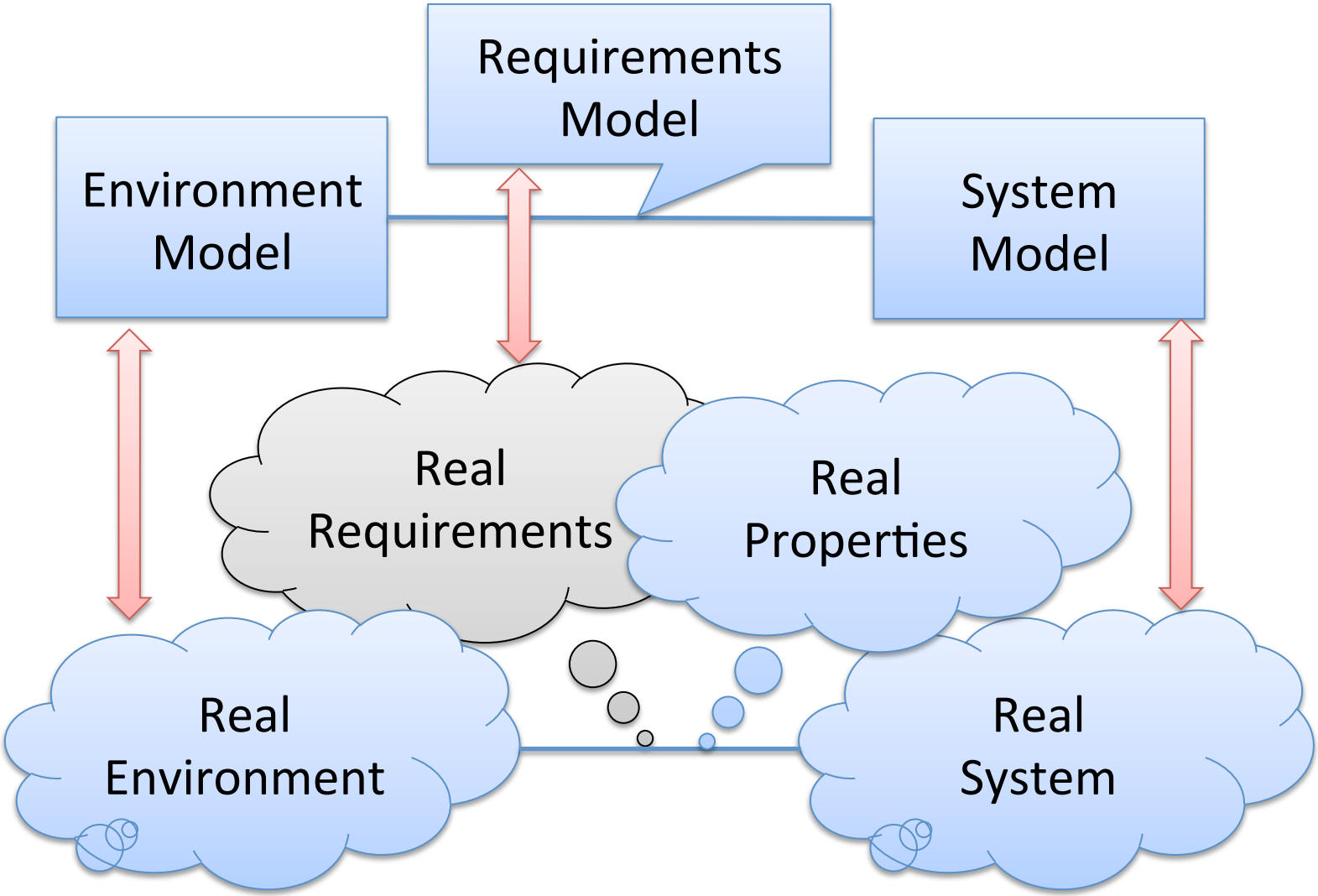

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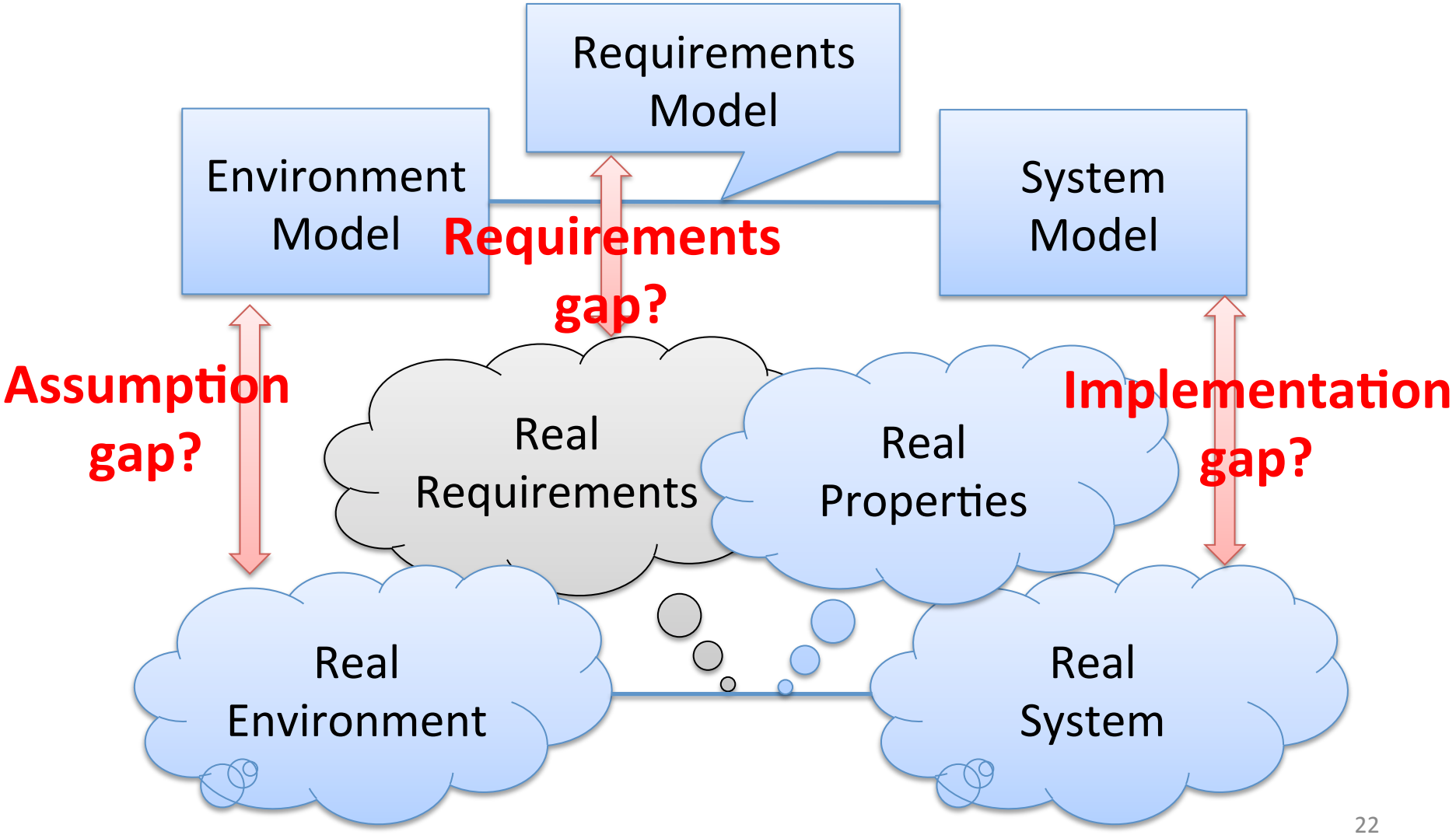
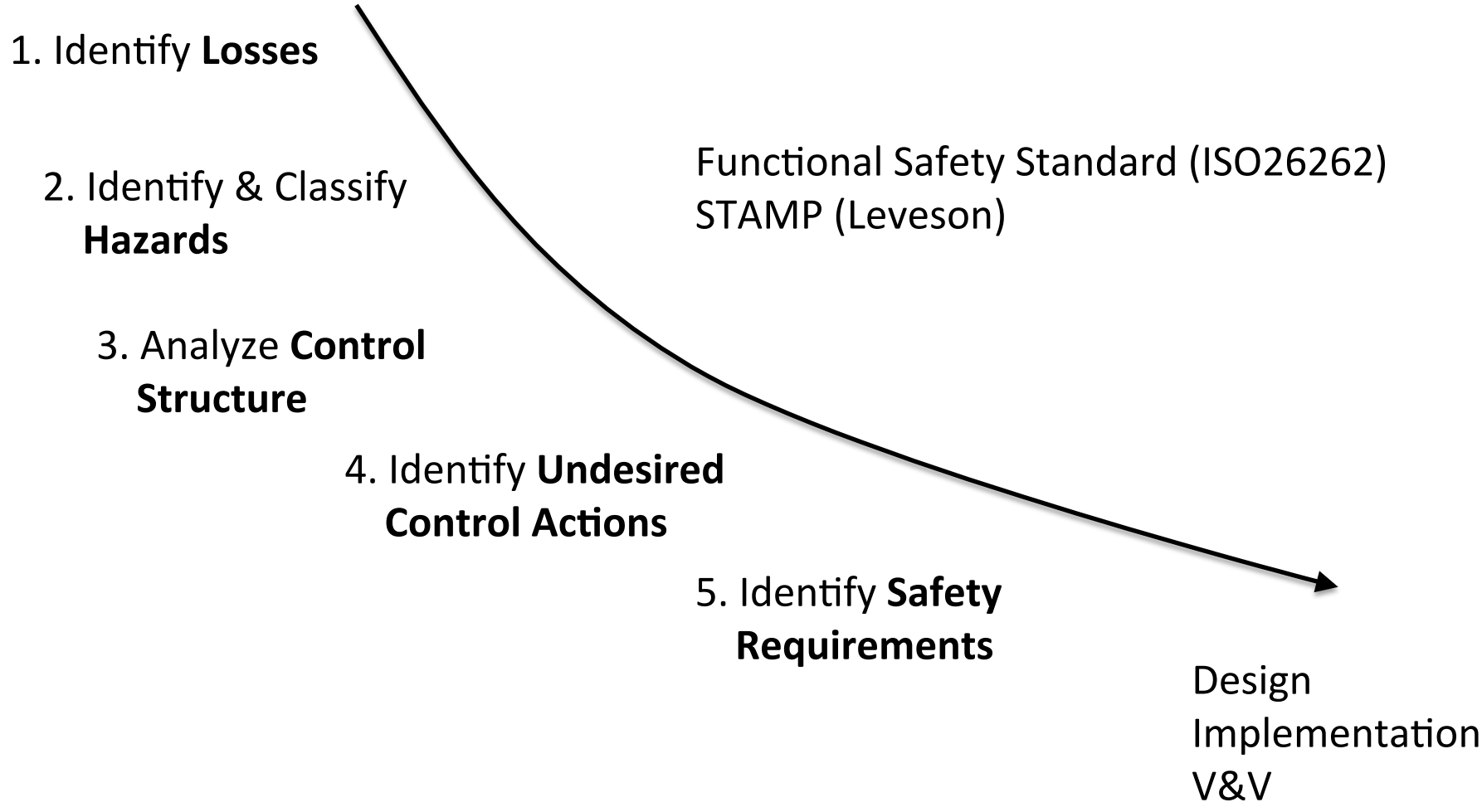
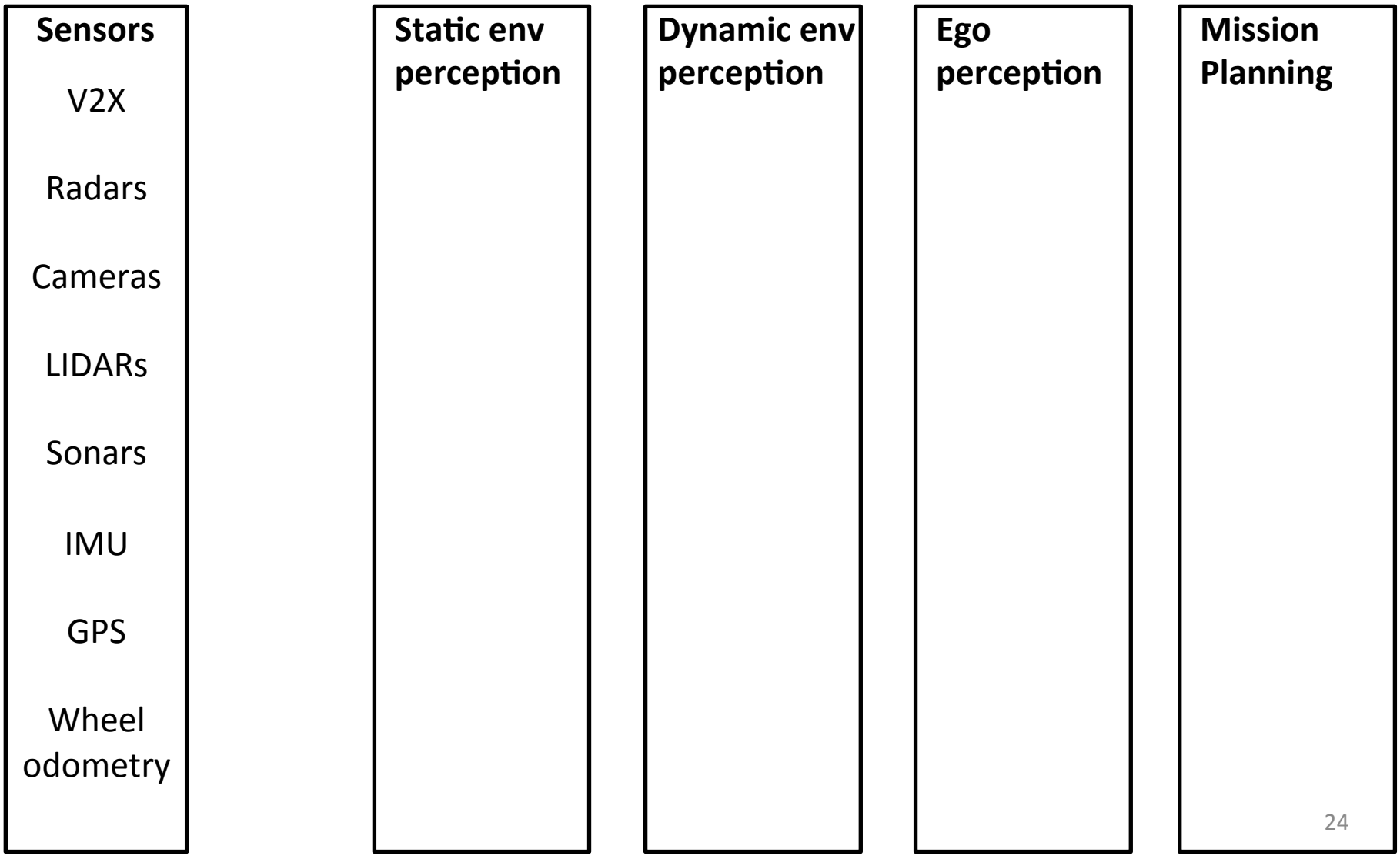


Safety Analysis



High-Level Functional Architecture



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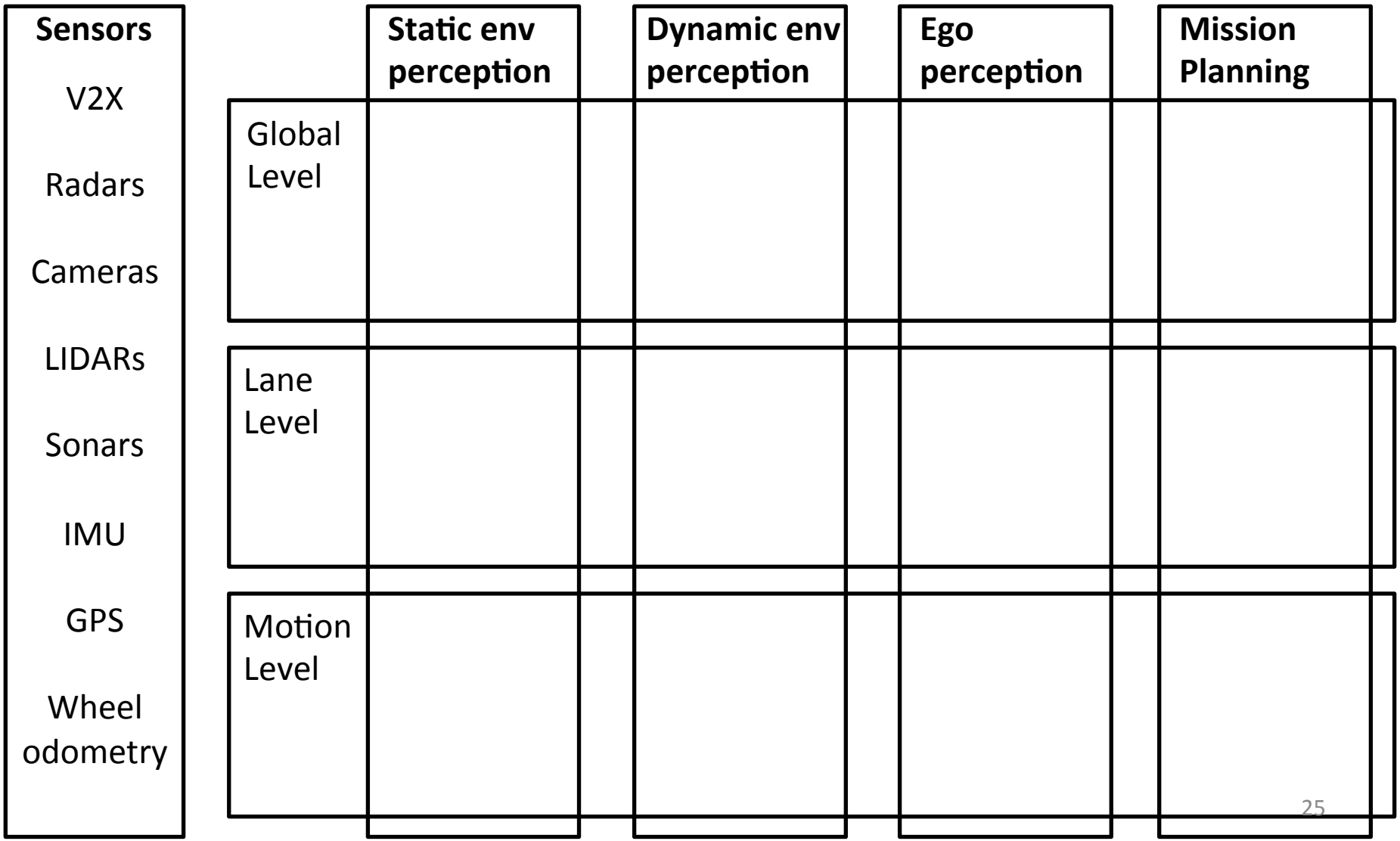

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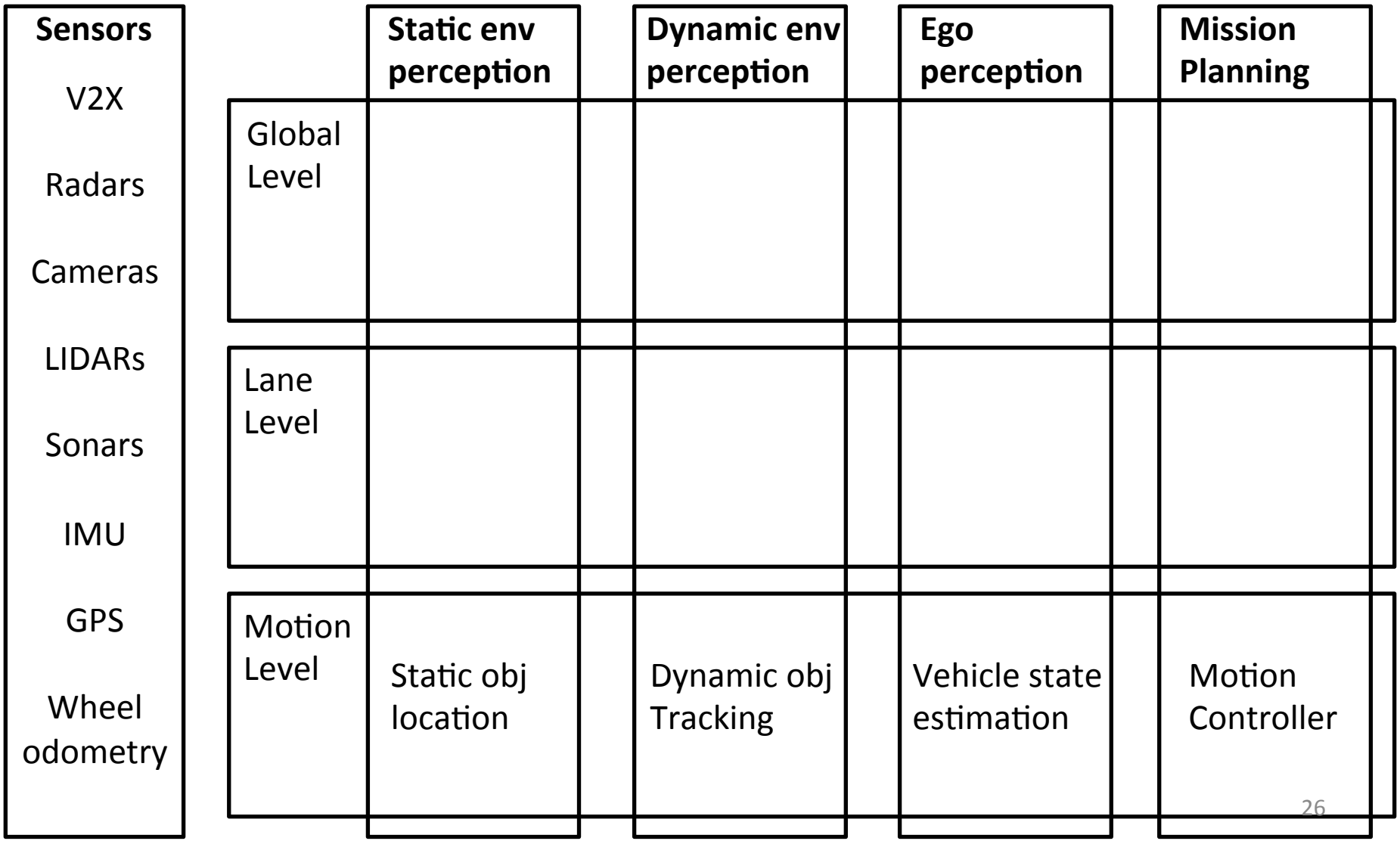
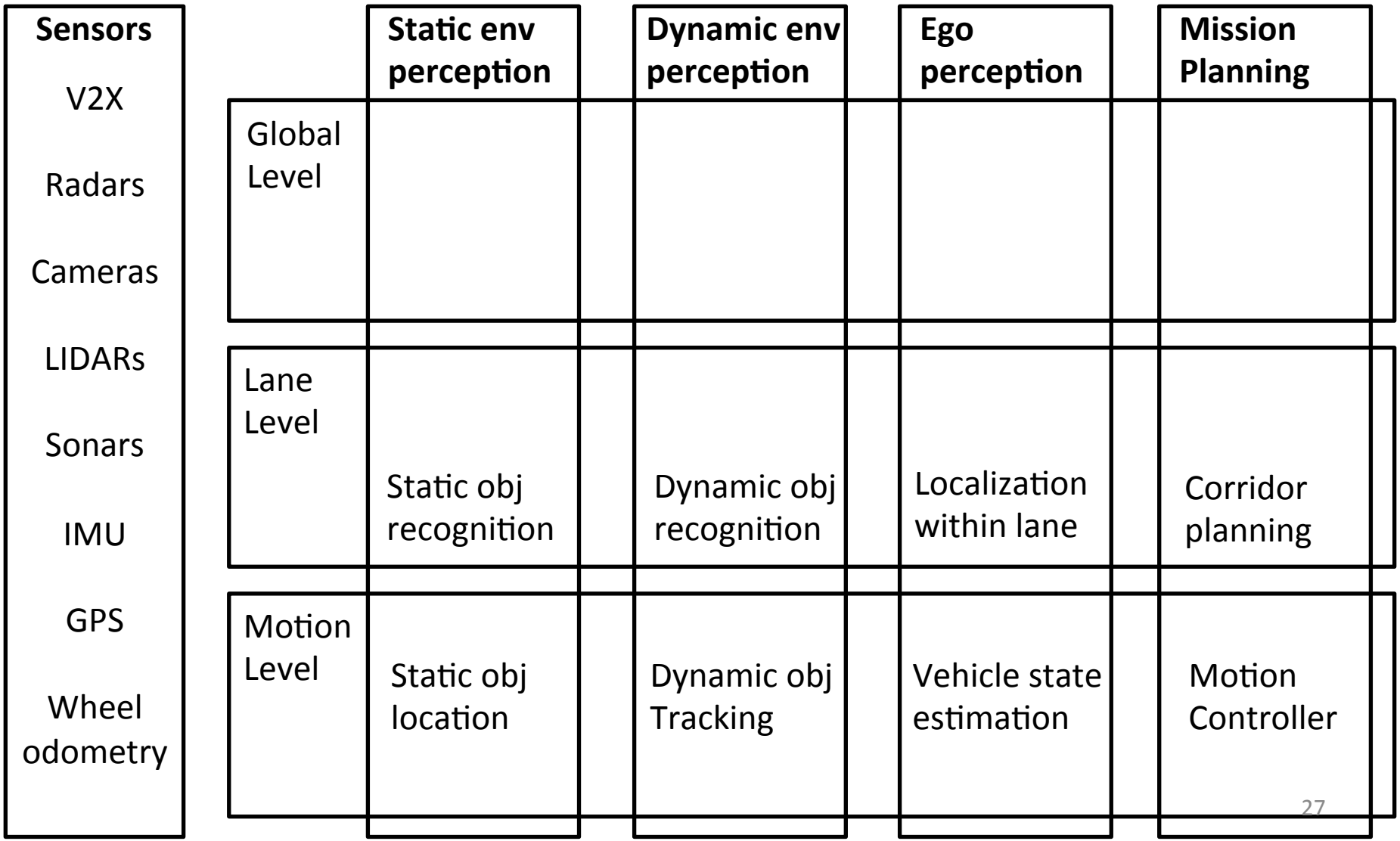


High-Level Functional Architecture



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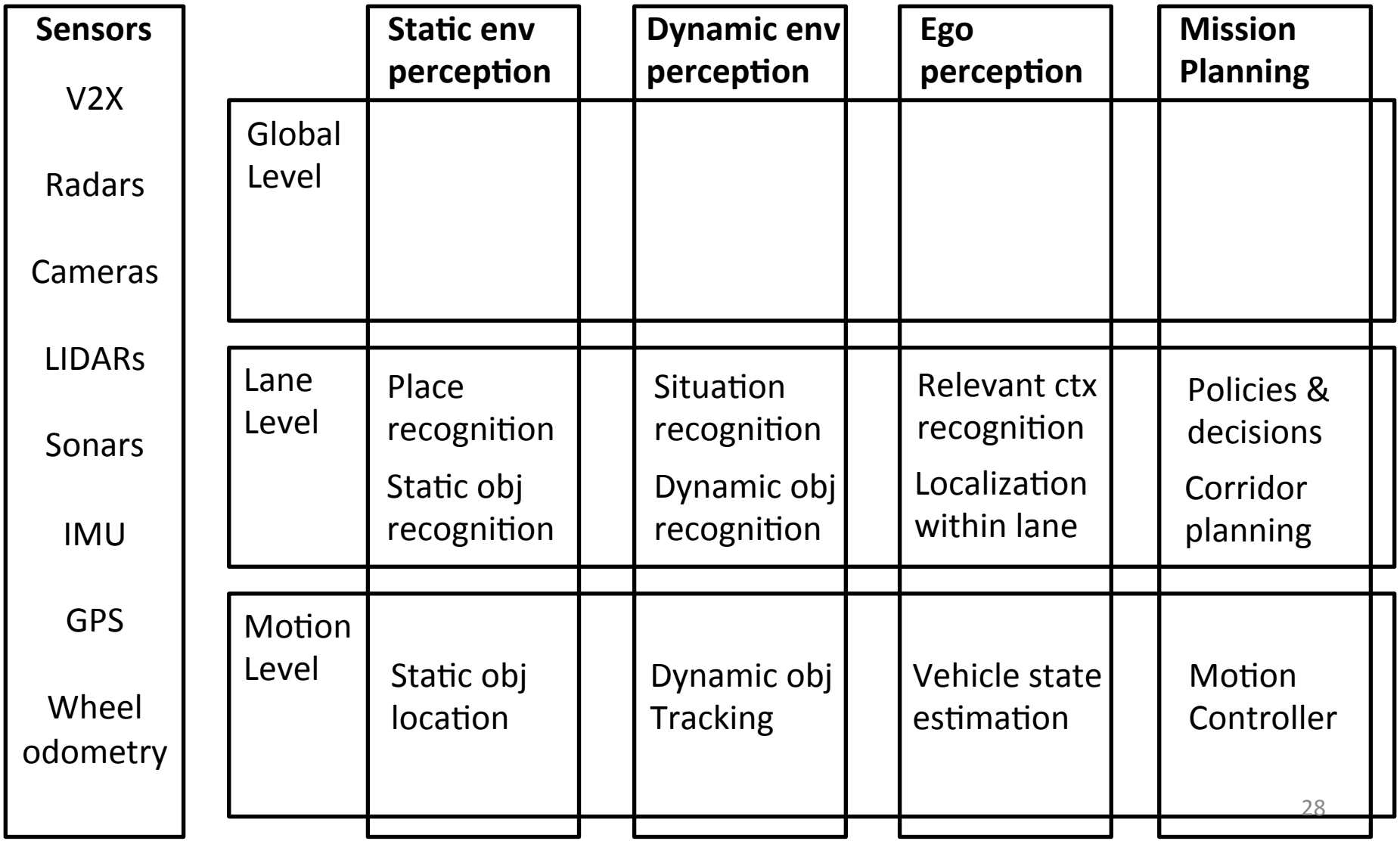


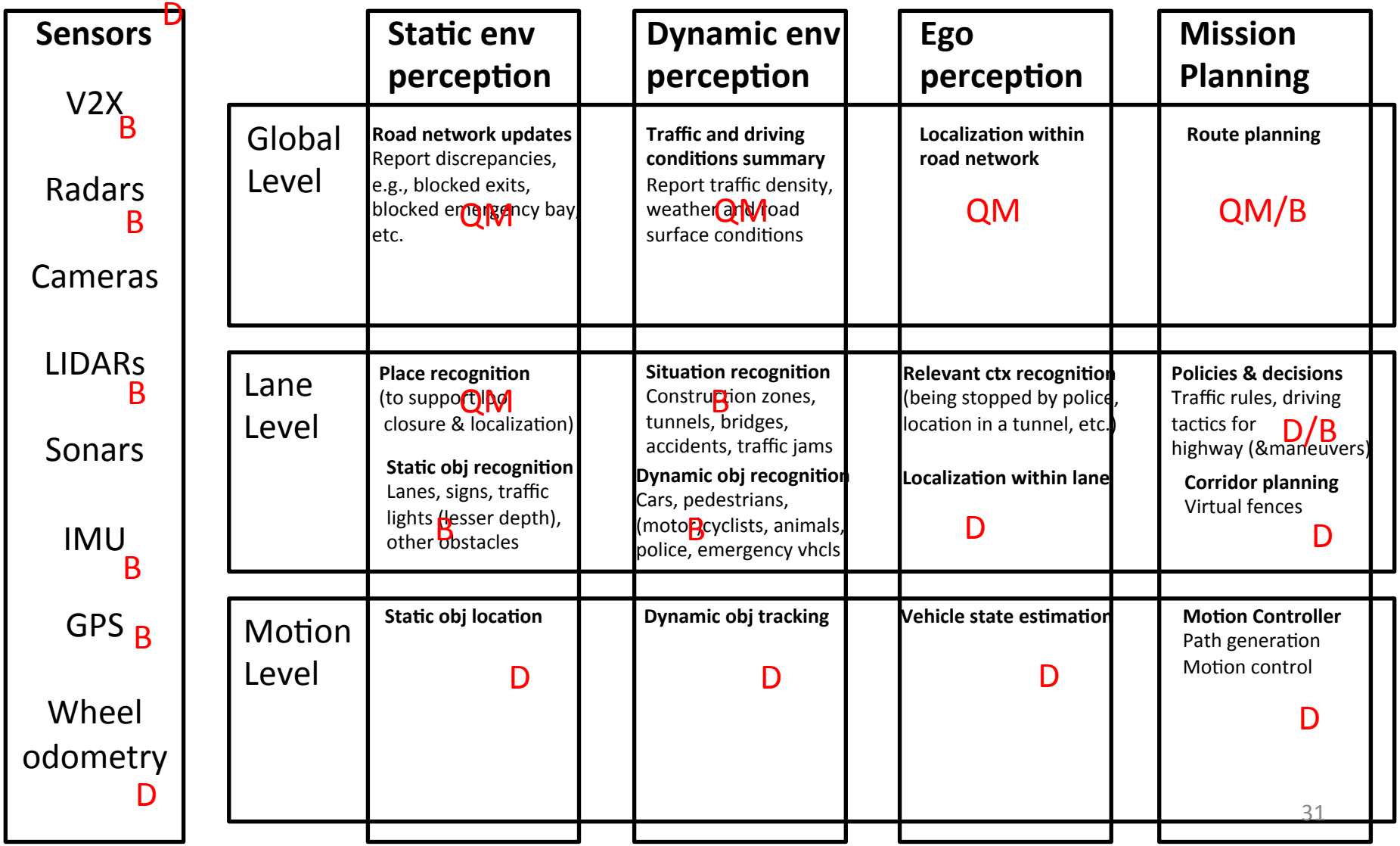
High-Level Functional Architecture

Sensors		Static env perception	Dynamic env perception	Ego perception	Mission Planning
V2X Radars Cameras LIDARs Sonars IMU GPS Wheel odometry	Global Level	Road network updates	Traffic and driving conditions summary	Localization within road network	Route planning
	Lane Level	Place recognition Static obj recognition	Situation recognition Dynamic obj recognition	Relevant ctx recognition Localization within lane	Policies & decisions Corridor planning
	Motion Level	Static obj location	Dynamic obj Tracking	Vehicle state estimation	Motion Controller

Highway Driving

Sensors		Static env perception	Dynamic env perception	Ego perception	Mission Planning
V2X Radars Cameras LIDARs Sonars IMU GPS Wheel odometry	Global Level	**Road network updates** Report discrepancies, e.g., blocked exits, blocked emergency bay, etc.	**Traffic and driving conditions summary** Report traffic density, weather and road surface conditions	**Localization within road network**	**Route planning**
	Lane Level	**Place recognition** (to support loo closure & localization) **Static obj recognition** Lanes, signs, traffic lights (lesser depth), other obstacles	**Situation recognition** Construction zones, tunnels, bridges, accidents, traffic jams **Dynamic obj recognition** Cars, pedestrians, (motor)cyclists, animals, police, emergency vhcls	**Relevant ctx recognition** (being stopped by police, location in a tunnel, etc.) **Localization within lane**	**Policies & decisions** Traffic rules, driving tactics for highway (&maneuvers) **Corridor planning** Virtual fences
	Motion Level	**Static obj location**	**Dynamic obj tracking**	**Vehicle state estimation**	**Motion Controller** Path generation Motion control

Highway Driving



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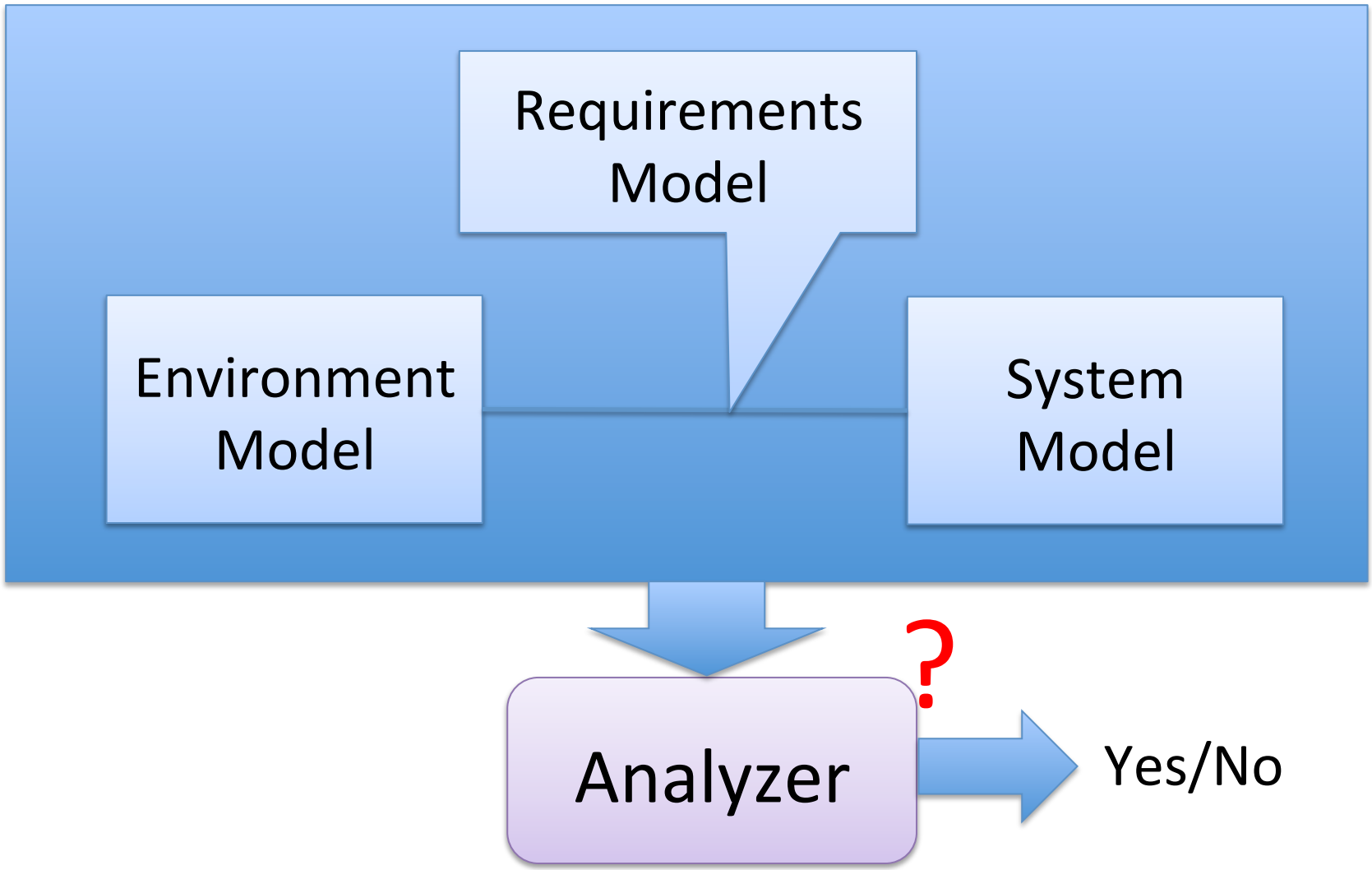

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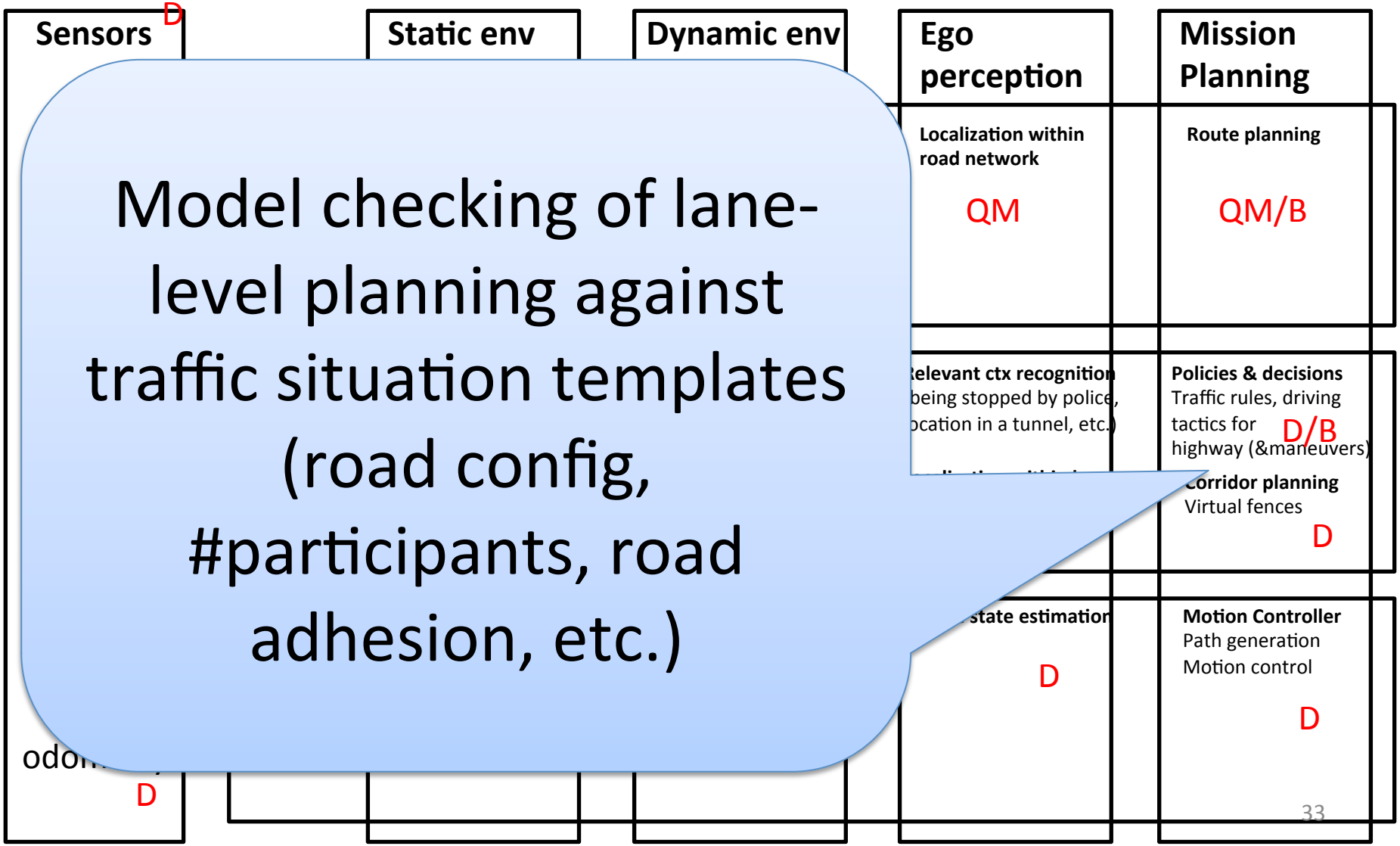

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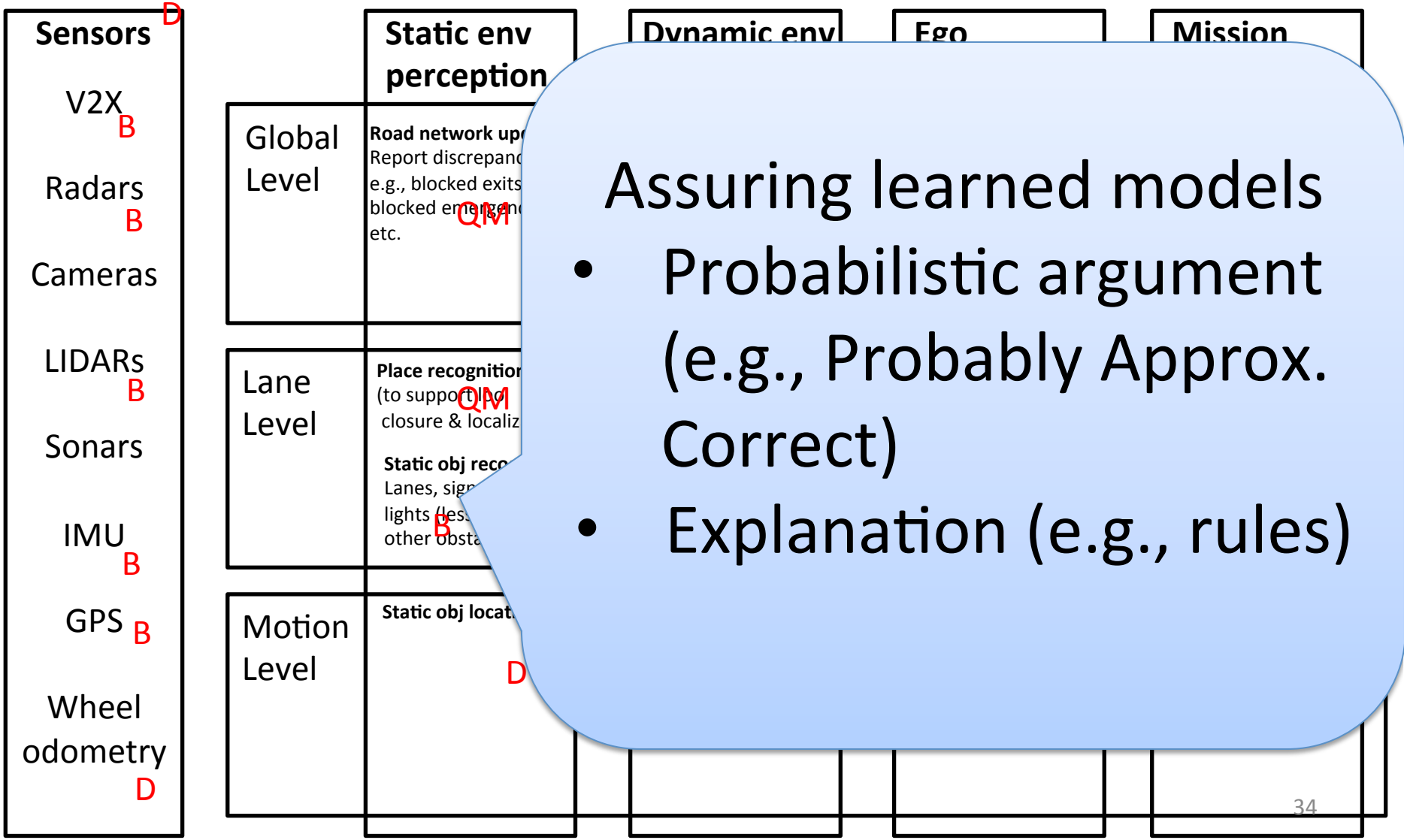
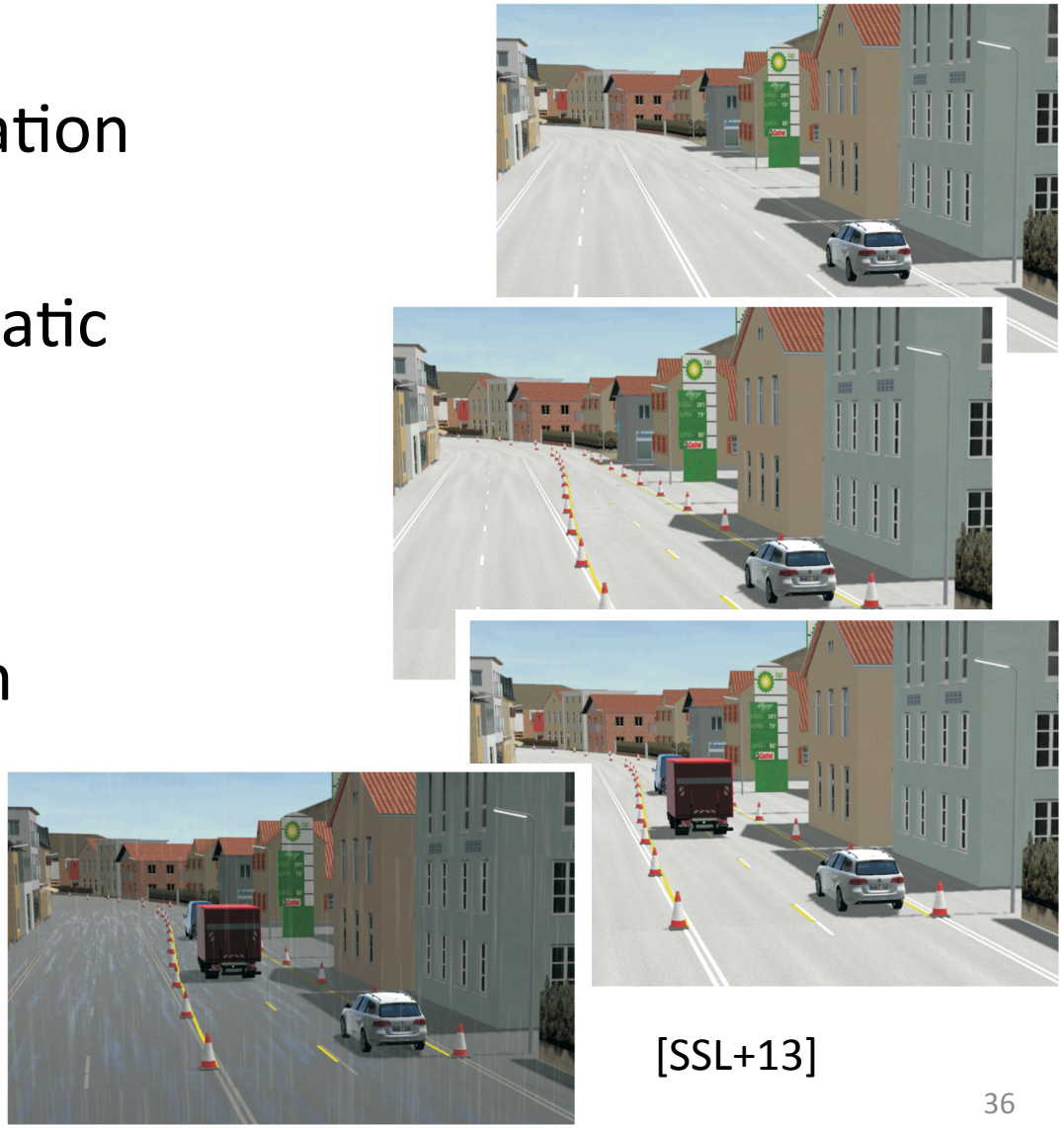


Testing

- Testing as a multi-objective optimization
  - Likelihood
  - Severity
- Generation of test data in a synthetic environment
  - Recording in the field
  - Fuzzing
  - Design of new situations

Test Design Levels

- Base road configuration
- Situation-specific static adaptation
- Situation-specific dynamic adaptation
- Weather and road conditions



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Testing Planners

Sensors	Static env	Dynamic env	Ego perception	Mission Planning
D			**Localization within road network** QM	**Route planning** QM/B
			Relevant ctx recognition being stopped by police, location in a tunnel, etc.)	**Policies & decisions** Traffic rules, driving tactics for highway (&maneuvers) D/B **Corridor planning** Virtual fences D
odom… D			…state estimation D	**Motion Controller** Path generation Motion control D

Testing Perception

Sensors		Static env perception	Dynamic env	Ego	Mission
V2X B Radars B Cameras LIDARs B Sonars IMU B GPS B Wheel odometry D	Global Level	**Road network u** Report discrepa e.g., blocked ex blocked emerge etc.			
	Lane Level	**Place recogniti** (to support lo closure & loca **Sta** Lane lights other ob			
	Motion Level	**Static obj loc**			

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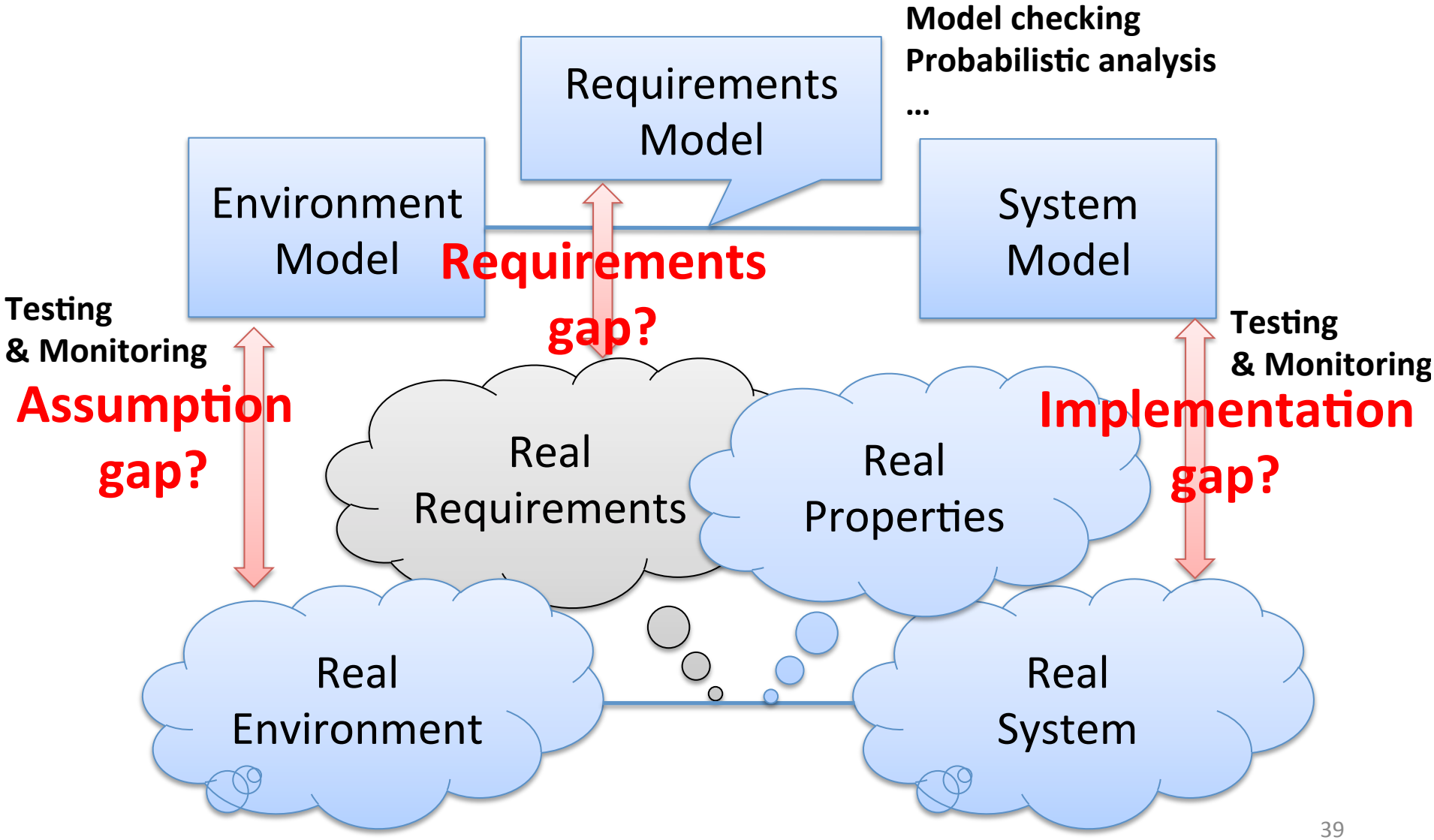
Model-Based Assurance



Reference for Slide 36

- [SSL+13] Schuldt, F.; Saust, F.; Lichte, B.; Maurer, M.; Scholz, S.: Effiziente systematische Testgenerierung für Fahrerassistenzsysteme in virtuellen Umgebungen. In: AAET2013