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# Sensor-relevant ODD Classification Framework

**Prepared for: ASAM OpenODD Ideation Workshop, 2020 APR 23**

**Prepared by: Michael Woon, Retrospect**

Driving Autonomous Vehicle Safety

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# Agenda

- **ODD Definition for proving performance (e.g. safety) requirements**
- **ODD Definition for sensing modalities**
  - Camera
  - LIDAR
  - Radar
- **Opportunities: Real world analysis**
  - Identifying relevant thresholds
  - Dependent variable analysis
  - Real world data validation

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# Defining the ODD

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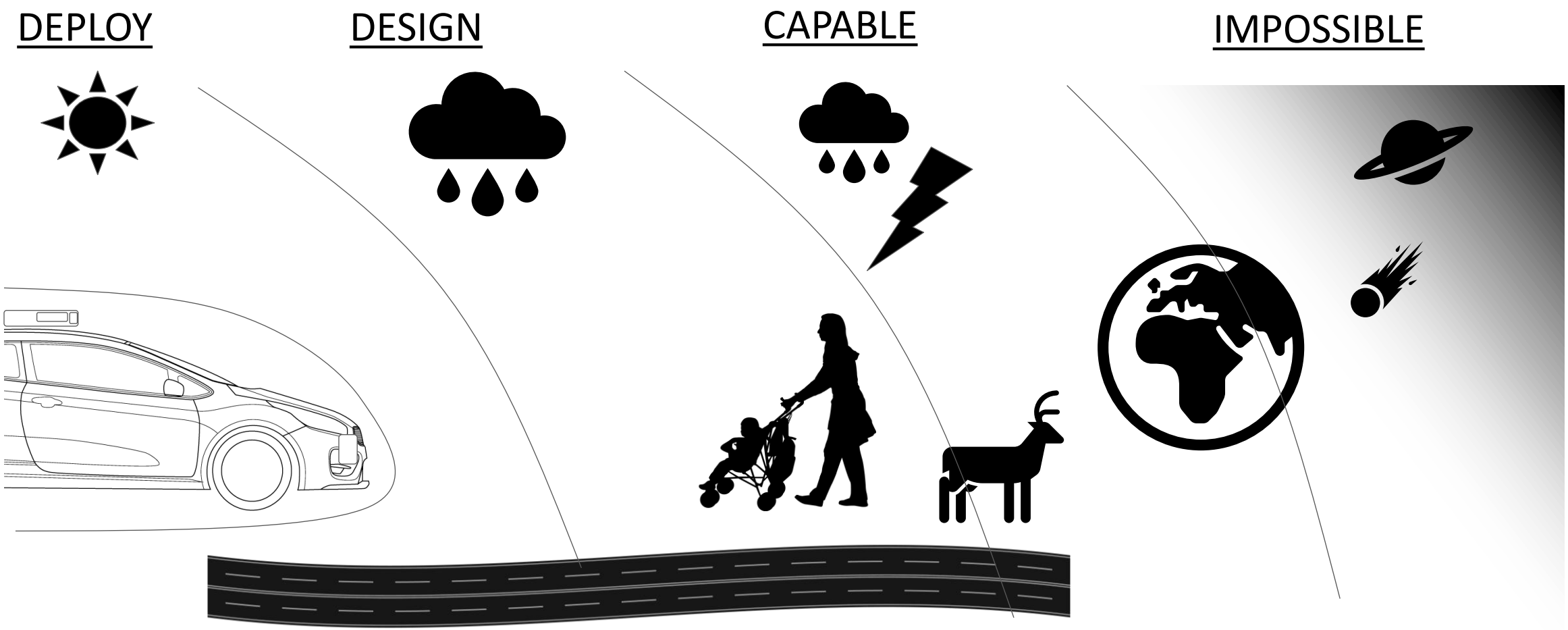

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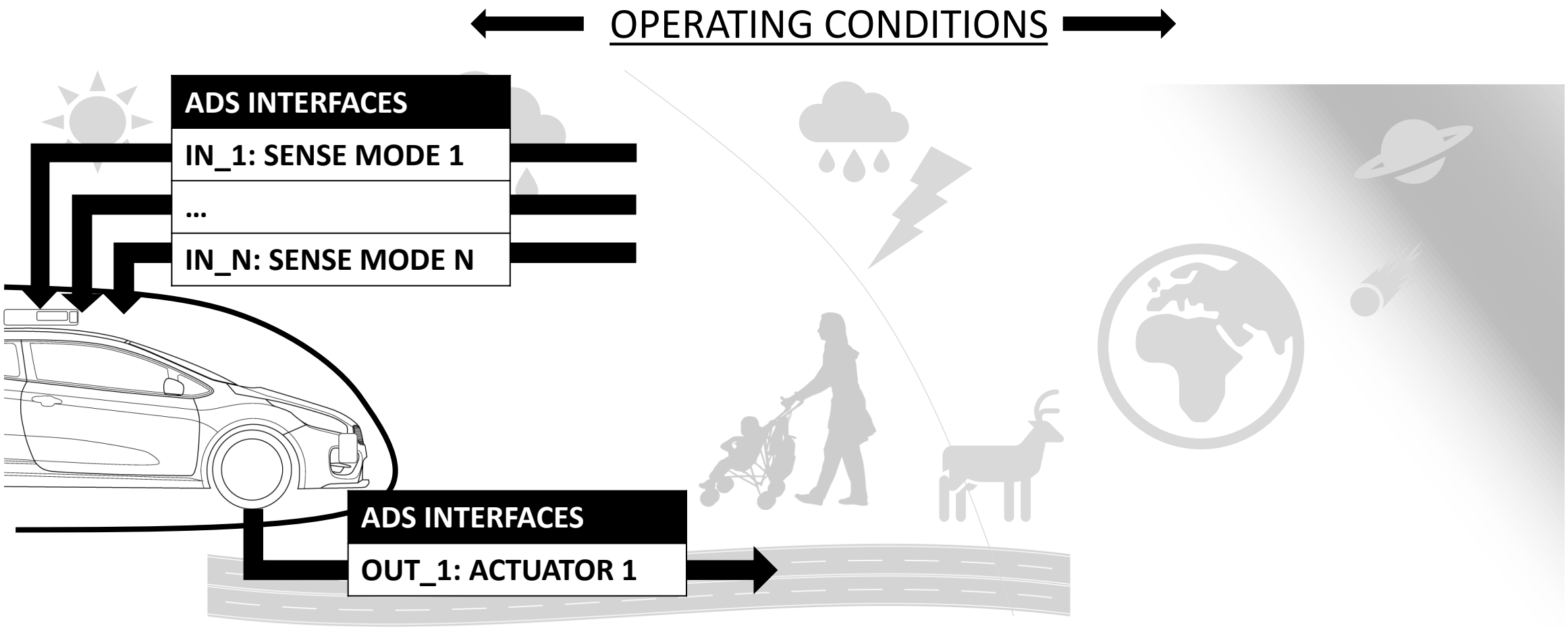


# Quantifying the ODD / Operating Conditions

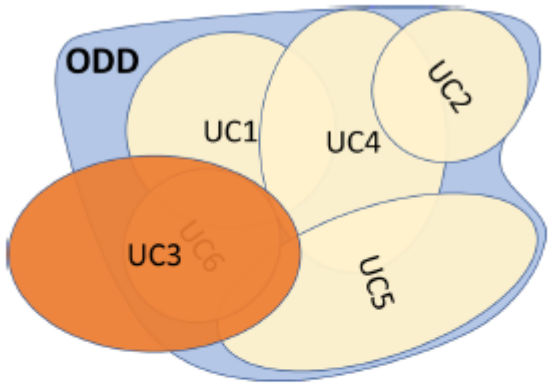



Fig. 2. Use cases (UCs) and the ODD. The ADS can only be released for UCs contained within the ODD, i.e. not UC3.

Towards an Operational Design Domain That Supports the Safety Argumentation of an Automated Driving System

Magnus Gyllenhammar, Rolf Johansson, Fredrik Warg, Dejiu Chen, Hans-Martin Heyn, Martin Sanfridson, Jan Söderberg, Anders Thorsén, Stig Ursing

**"We suggest that the ODD is quantitatively defined for all applicable [Operating Conditions]"**

Source: Towards an Operational Design Domain That Supports the Safety Argumentation of an Automated Driving System

# Translating ODD / OC to Performance Requirements

**The ADS Function shall (produce output value) within (ms) if (conditional statement of inputs is true).**

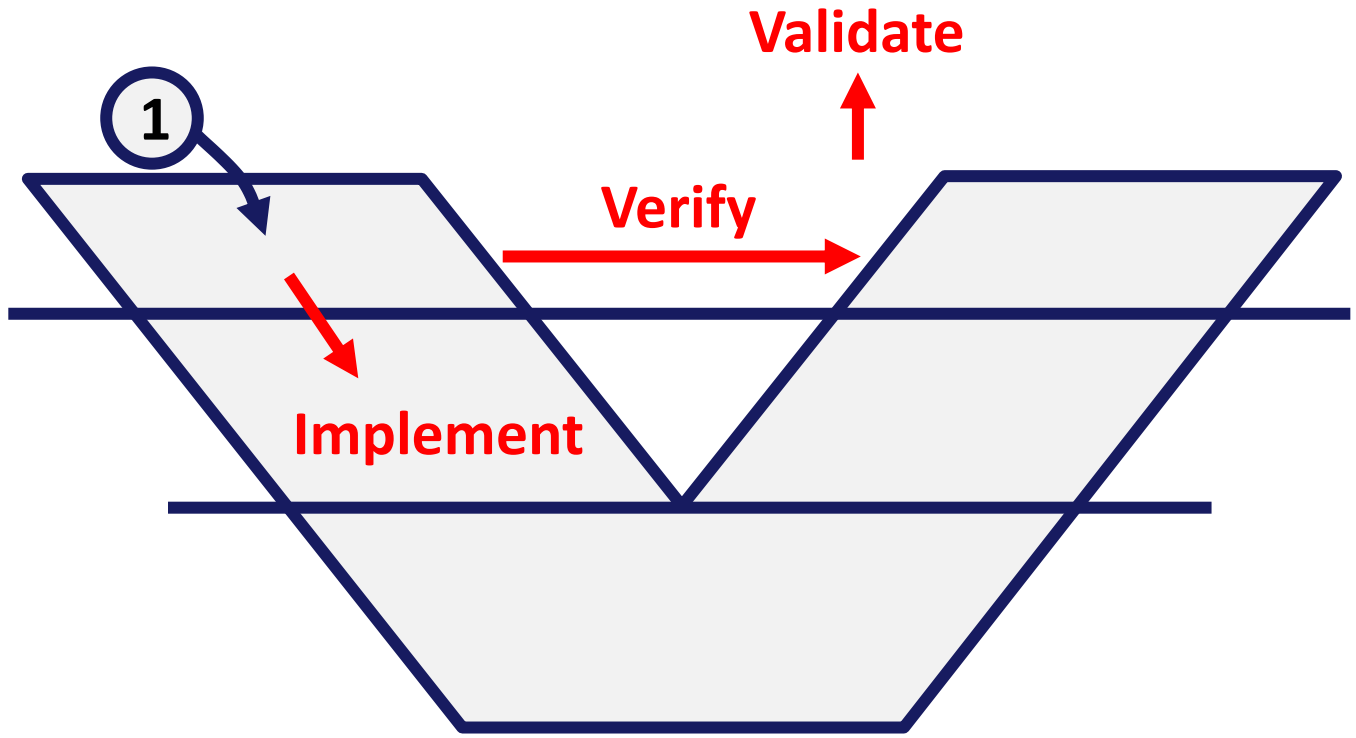
Output Performance

Operating Condition

**The ADS Perception shall create the VRU Object Track within 250 ms if an unobscured PEDESTRIAN is present in the area less than 60 m in front of the EGO and less than 15 m to the right of the EGO.**

# Translating ODD / OC to Performance Requirements

- **Quantify ODD or Operating Conditions in ADS interface-relevant frame**
- **Implementable**
- **Verifiable / Testable**
- **Validateable**
  - Tests
  - Analysis



# Quotes on the ADS Requirements Problem (2020 alone)

+ “We have kind of been waiting for **some sort of industry standard**” Dmitry Polishchuk, the head of Russian tech giant Yandex’s [1]
+ Derek Kan, U.S. secretary for policy at the U.S. Department of Transportation, stressed **the need for objective and agreed-upon measures** of driverless systems performance [1]
+ Transportation Secretary Elaine Chao announced Automated Vehicles 4.0 (AV 4.0), new guidelines regarding self-driving cars that seek to **promote “voluntary consensus standards”** among autonomous vehicle developers [1]
+ NTSB has recommended that the department **require more testing and proof of safety** before large numbers of vehicles are allowed on public roads [2]
+ AV developers have **long kept their methods close** to the vest, disclosing scant data to the public [3]
+ Today, **neither industry nor government can assess the safety** of self-driving cars [3]
+ **Without tools or common yardsticks**, tech suppliers are working in the dark [3]
+ The goal is “**mapping different standards for autonomous vehicles**,” said Mariani. “This is very important because such a mapping can help experts or corporations decide where to invest their time and resources.” [3]
+ We suggest that **the ODD is quantitatively defined** for all applicable [Operating Conditions] [4]

1. https://venturebeat-com.cdn.ampproject.org/c/s/venturebeat.com/2020/01/10/ai-weekly-autonomous-cars-need-better-safety-metrics-to-move-the-industry-forward/amp/
2. https://www.consumerreports.org/autonomous-driving/congress-debates-autonomous-vehicles-car-safety/
3. https://www.eetimes.com/a-wave-of-av-safety-standards-to-hit-in-2020/
4. Towards an Operational Design Domain That Supports the Safety Argumentation of an Automated Driving System

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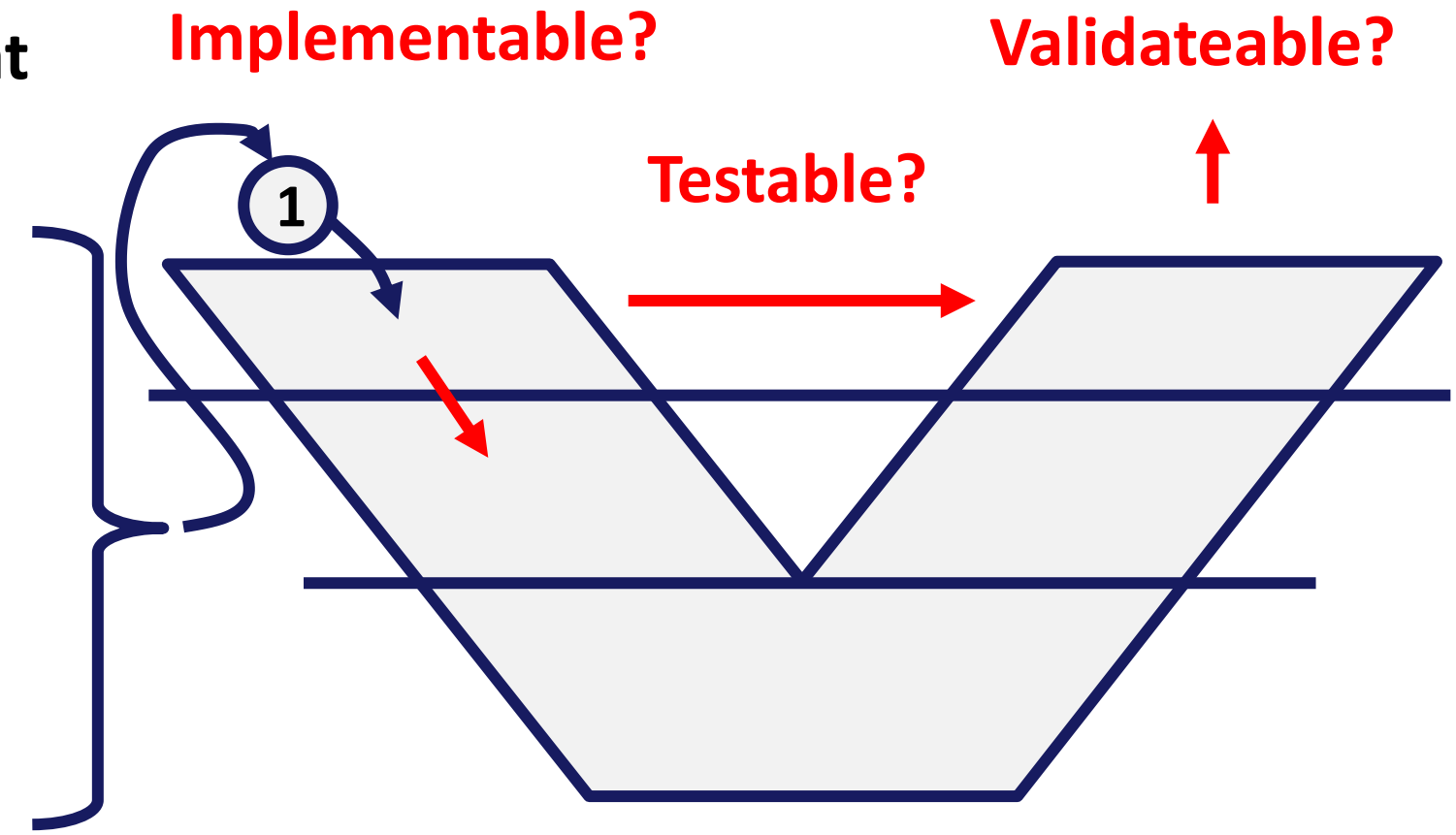
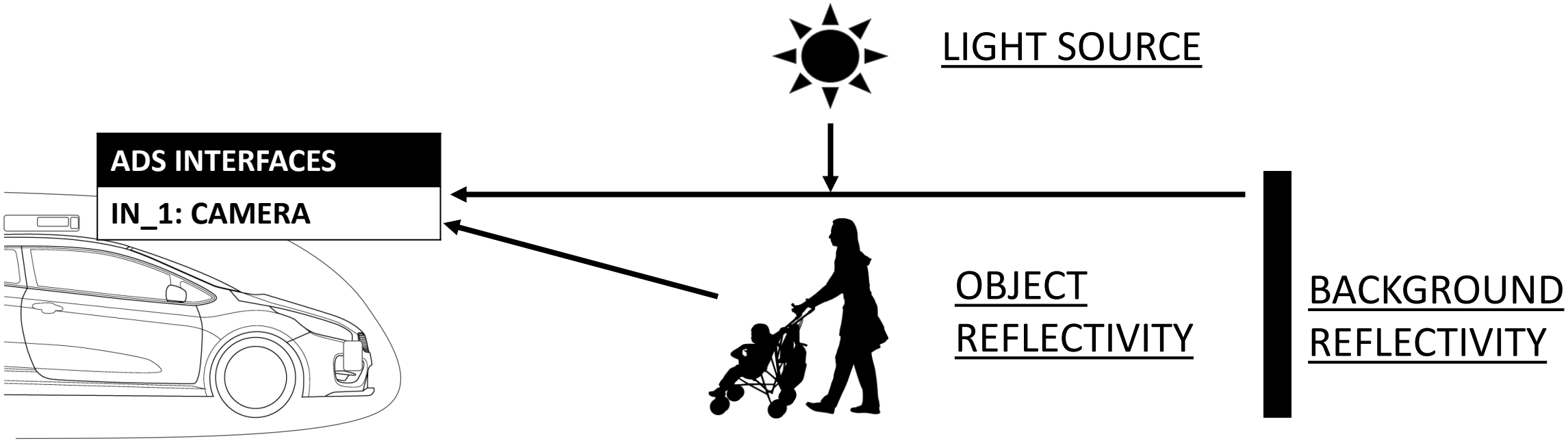
# ODD and Sensing Modalities

# Perception Complexity

**How do you articulate what the product must do?**



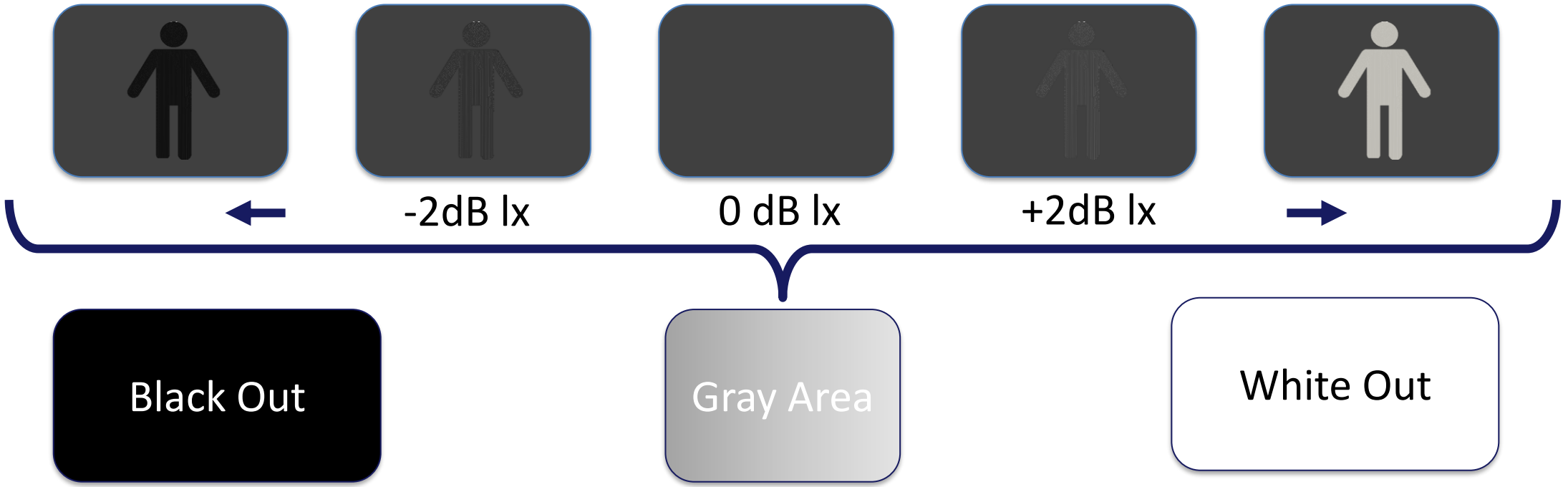
# Sensor-relevant ODD description



# Technical Challenges – Dynamic range performance

***PERCEPTION***

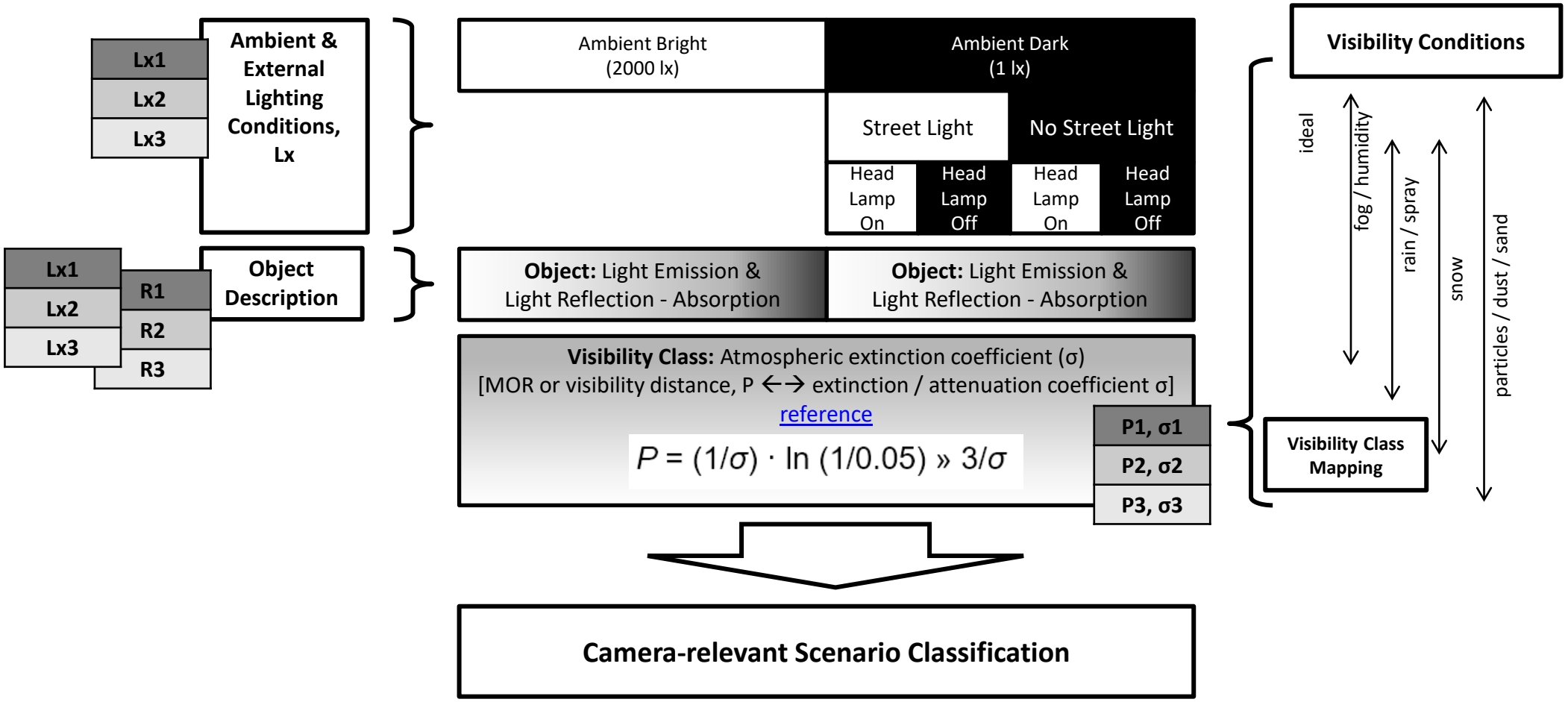
***(Example of camera sensing modality)***



# Sensor-relevant ODD classification framework

| Camera-relevant ODD Classification | | | | |
|---|---|---|---|---|
| CAMERA ODD CLASS 1 |  >10 dB lx |  |  |  |
| CAMERA ODD CLASS 2 |  3-10 dB lx |  |  |  |
| CAMERA ODD CLASS 3 |  2-3dB lx |  |  |  |

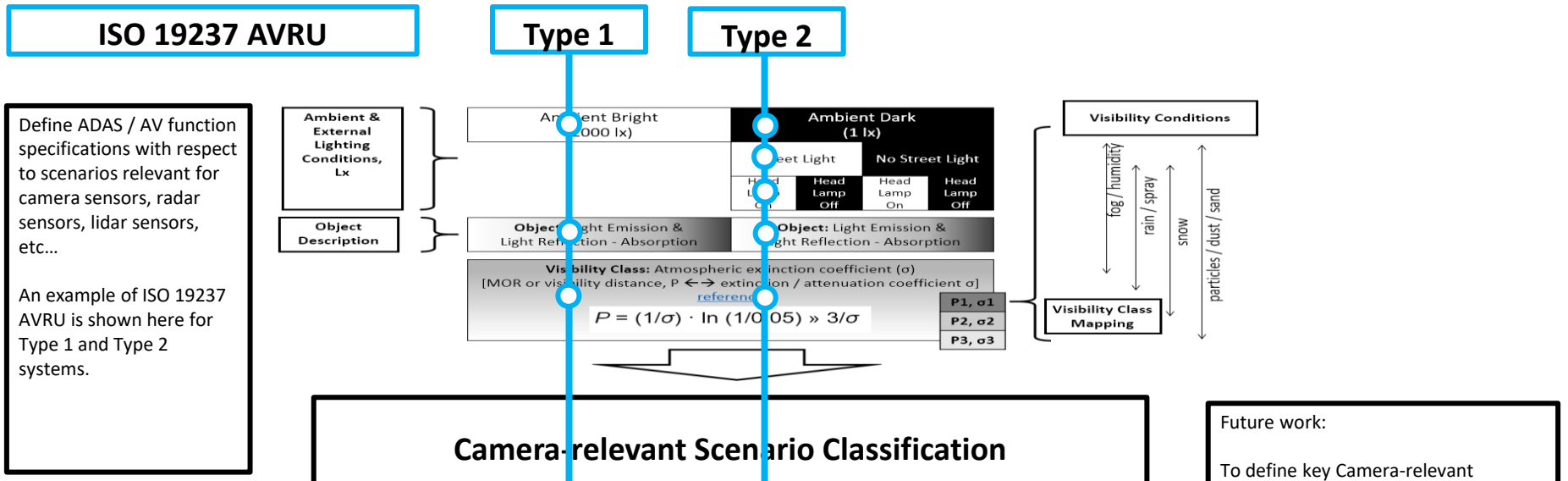
# Proposed “Camera-Relevant ODD Classification”



# Mapping ISO 19237 Performance Requirements

Define ADAS / AV function specifications with respect to scenarios relevant for camera sensors, radar sensors, lidar sensors, etc…

An example of ISO 19237 AVRU is shown here for Type 1 and Type 2 systems.




**Camera-relevant Scenario Classification**

**ADAS / AV Function**

**AVRU**

| | CAM class 1 | CAM class 2 | CAM class 3 | CAM class 4 |
|---|---|---|---|---|
| Func Spec 1 | | | | |
| Func Spec 2 | | | | |
| Func Spec 3 | | | | |
| Func Spec 4 | | | | |

Future work:

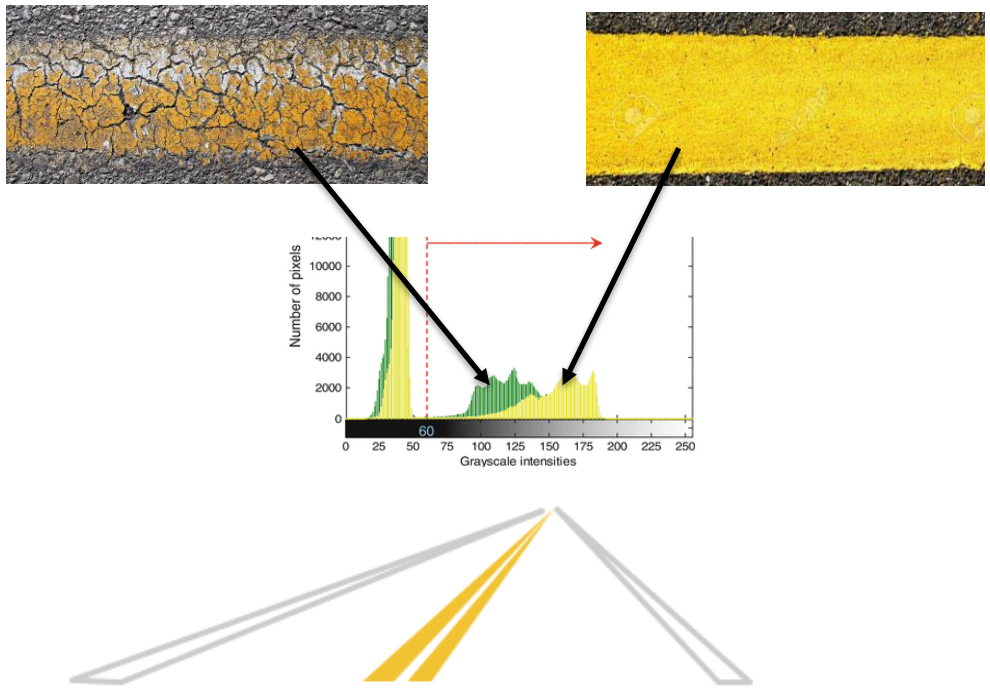
To define key Camera-relevant Scenario Classification terms (contrast ratio, etc.)

To map many independent scenario parameters to unique Camera-relevant Scenario Classes (OpenSCENARIO 1, 2, etc.)

Specify functional requirements for each Camera-relevant Scenario Class

Actor / ego path variations, add'l sensor-relevant classes, etc.

# Other Camera Examples




Pattern length,
Paint length,
Gap length,
Paint fade, etc.

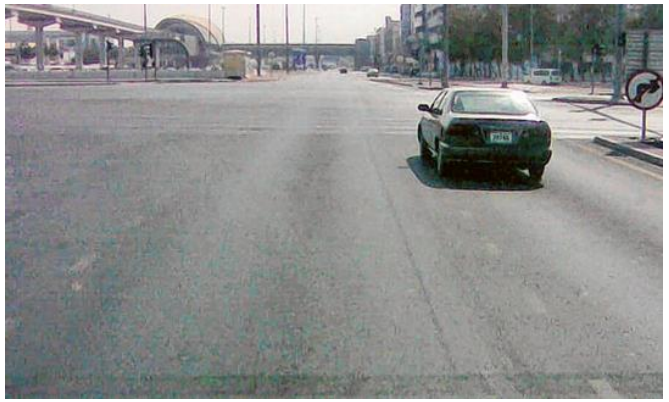



**Figure 1. Photo pavement markings with known retroreflectivity levels**

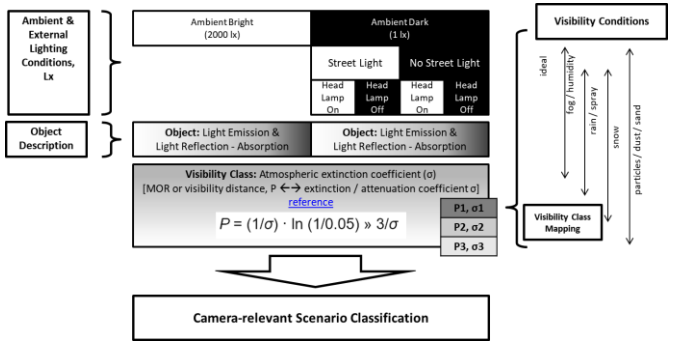
*(This photo shows an example of markings with known retroreflectivity (shown in yellow). It is not necessary to include multiple markings like shown when using the calibrated marking method. These markings are 30-meters from the observer, representing the standard 30-meter measurement geometry used as a standard for pavement marking retroreflectivity)*

**Figure 5. Typical Mobile Pavement Marking Retroreflectivity Measurement Device**

US DOT FHWA “Methods for Maintaining Pavement Marking Retroreflectivity” FHWA-SA-14-017 October 2014

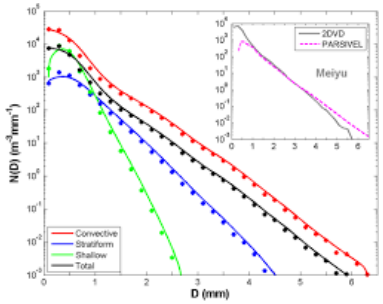
# Sensor Modalities for ODD Classification

## CAMERA



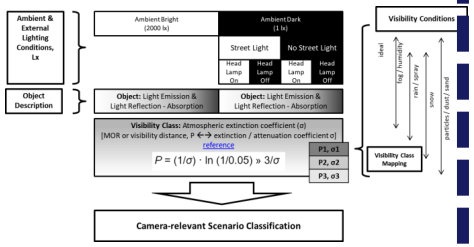

| Environmental Scenario Class |
|---|
| Camera ES Class 1 |
| Camera ES Class 2 |
| Camera ES Class 3 |

## LIDAR



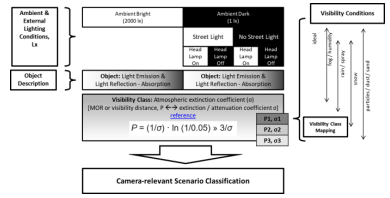

| Environmental Scenario Class |
|---|
| Camera ES Class 1 |
| Camera ES Class 2 |
| Camera ES Class 3 |

## RADAR




| Environmental Scenario Class |
|---|
| Camera ES Class 1 |
| Camera ES Class 2 |
| Camera ES Class 3 |

## INFRARED…



| Environmental Scenario Class |
|---|
| Camera ES Class 1 |
| Camera ES Class 2 |
| Camera ES Class 3 |

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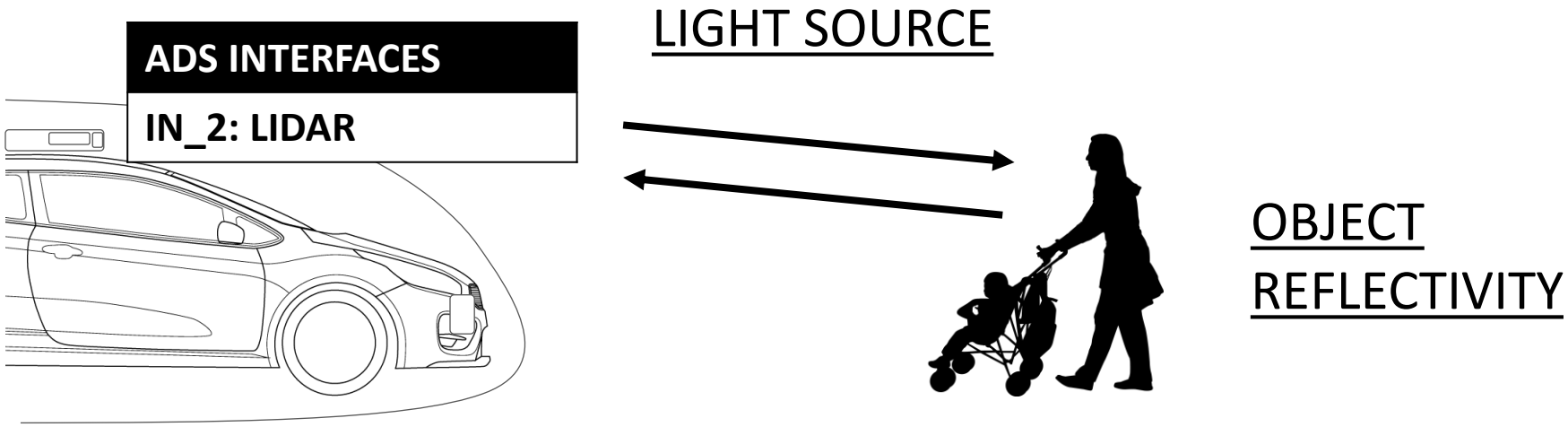
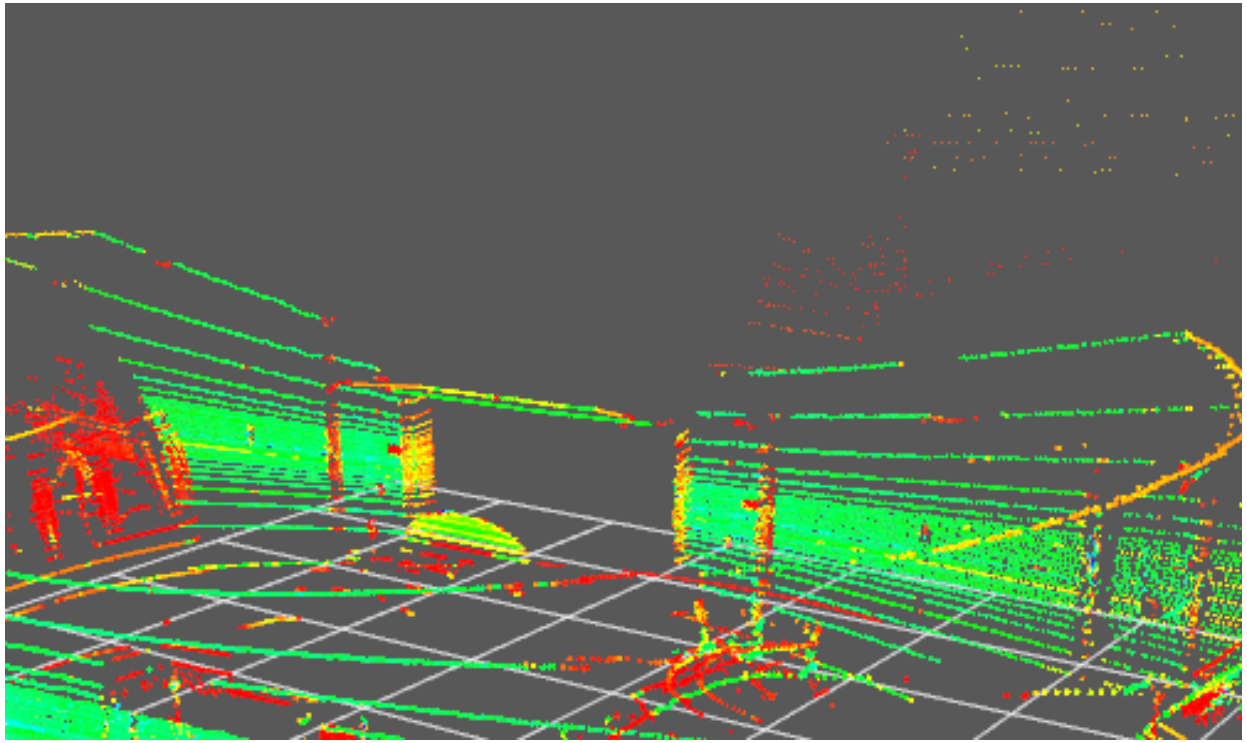
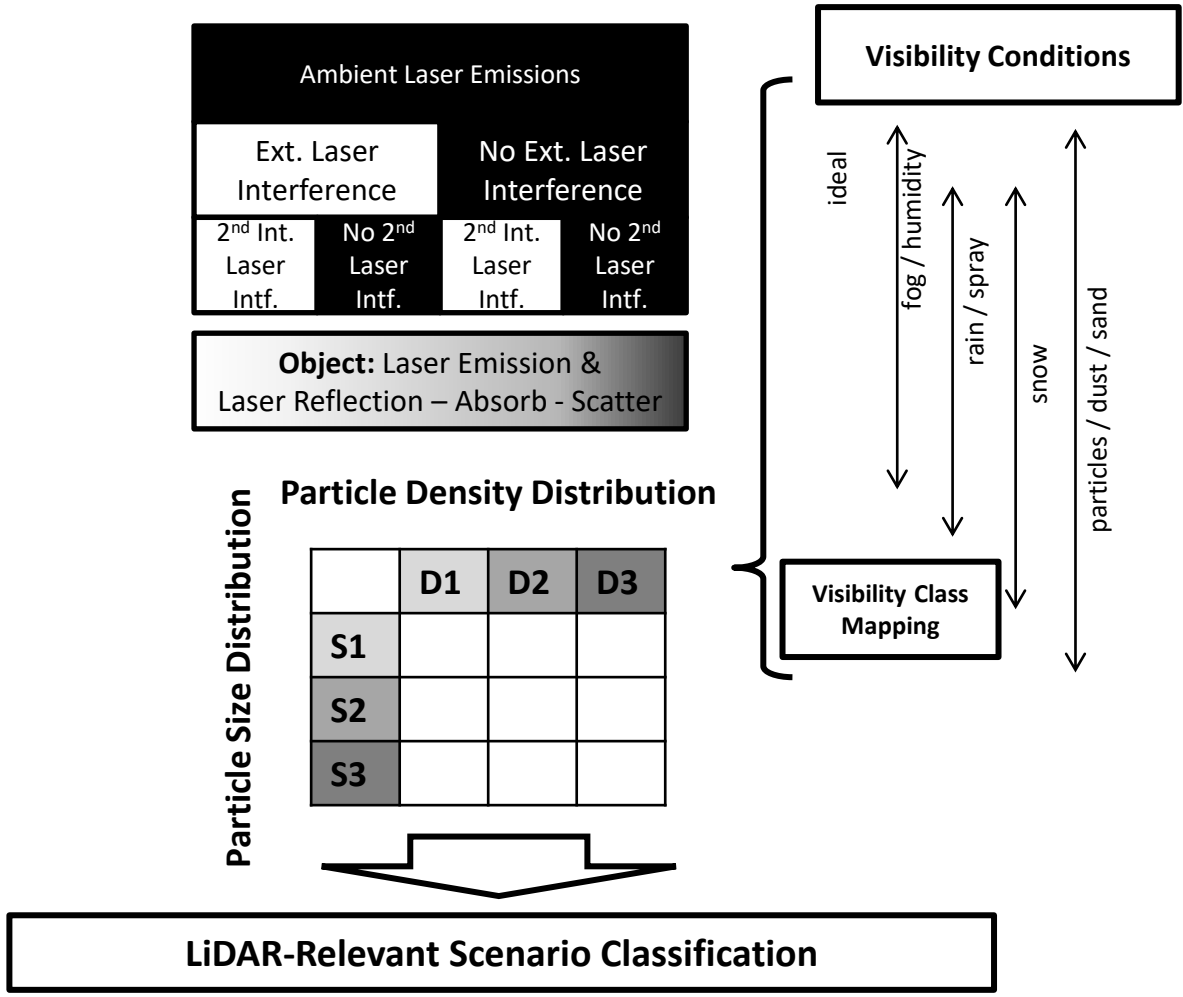
# LIDAR-Relevant ODD Classification Framework

# LIDAR-relevant ODD description



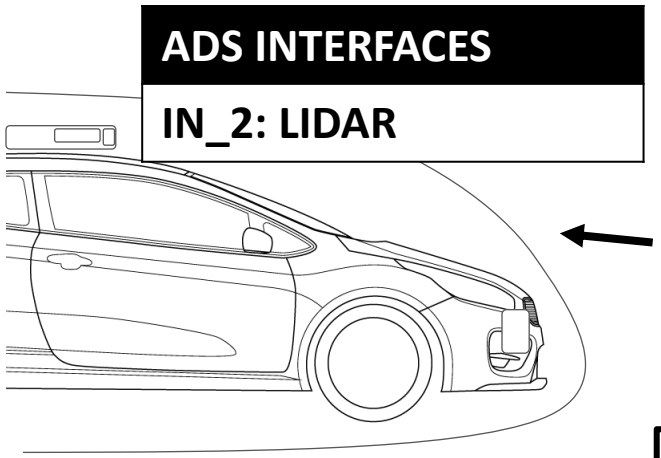
# LIDAR specific considerations





# LIDAR-relevant ODD description

## LIGHT SOURCE



**ADS INTERFACES**

**IN_2: LIDAR**

**Particle Density Distribution**

**Particle Size Distribution**

| Diam. | #/m³ 10^-1 | D1 | 10^2 | D2 | >10^4 | D3 |
|---|---|---|---|---|---|---|
| 2 mm | S1 | | | | | |
| 4 mm | S2 | | | | | |
| >8 mm | S3 | | | | | |

**Environmental Conditions**

ideal

fog / humidity

rain / spray

snow

particles / dust / sand

**LIDAR Class Mapping**

| R1 |
|---|
| R2 |
| R3 |

OBJECT REFLECTIVITY

**LIDAR-Relevant Scenario Classification**

| | LIDAR CLASS 1 | LIDAR CLASS 2 | LIDAR CLASS 3 | LIDAR CLASS 4 |
|---|---|---|---|---|
| LIDAR Func Perf Spec 1 | | | | |

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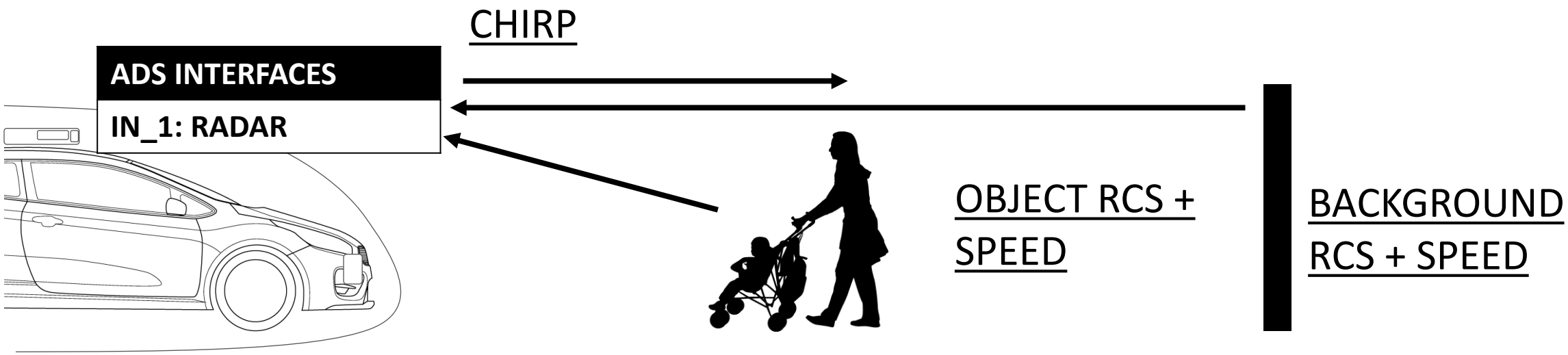
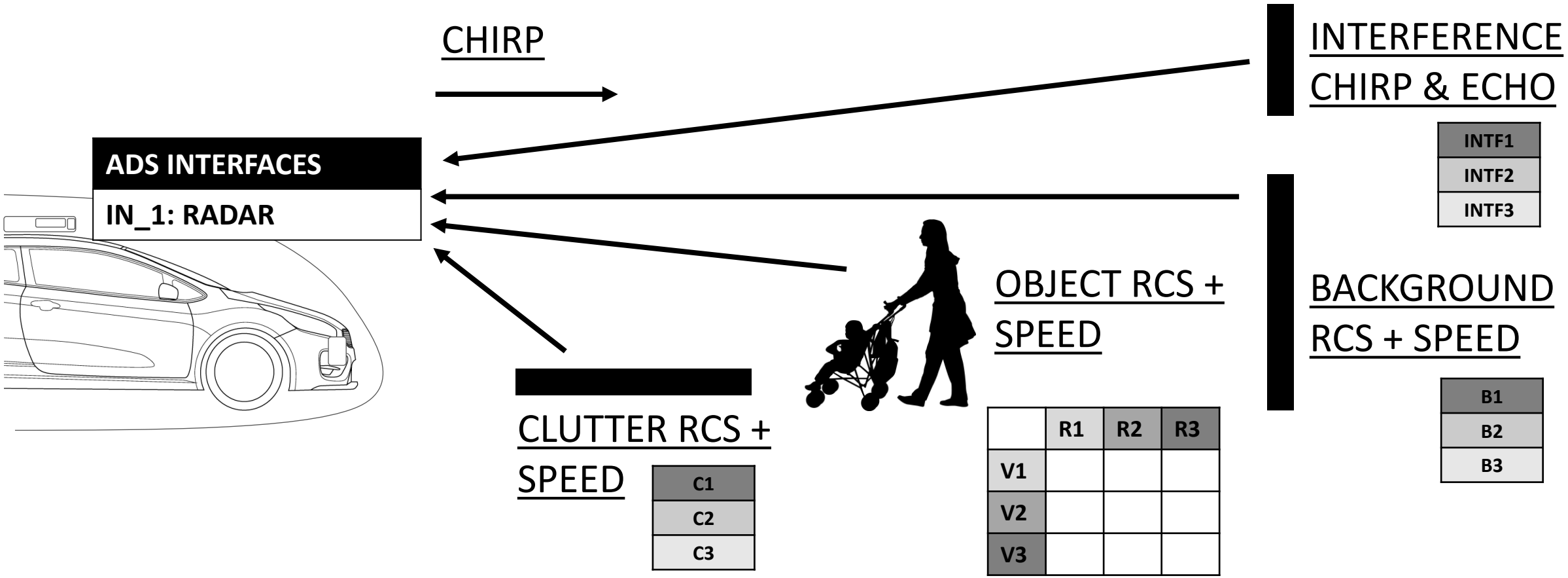
# Radar-Relevant ODD Classification Framework

# Radar-relevant ODD description



# Radar-relevant ODD description



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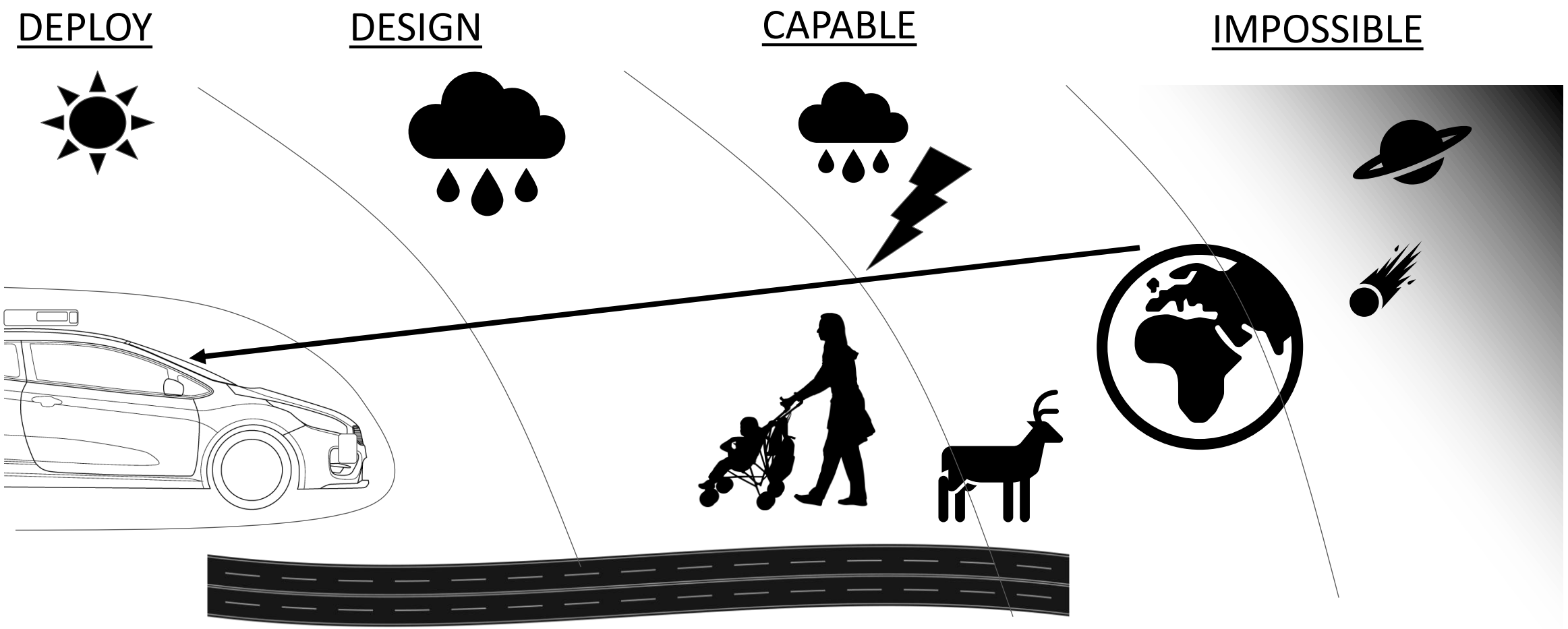
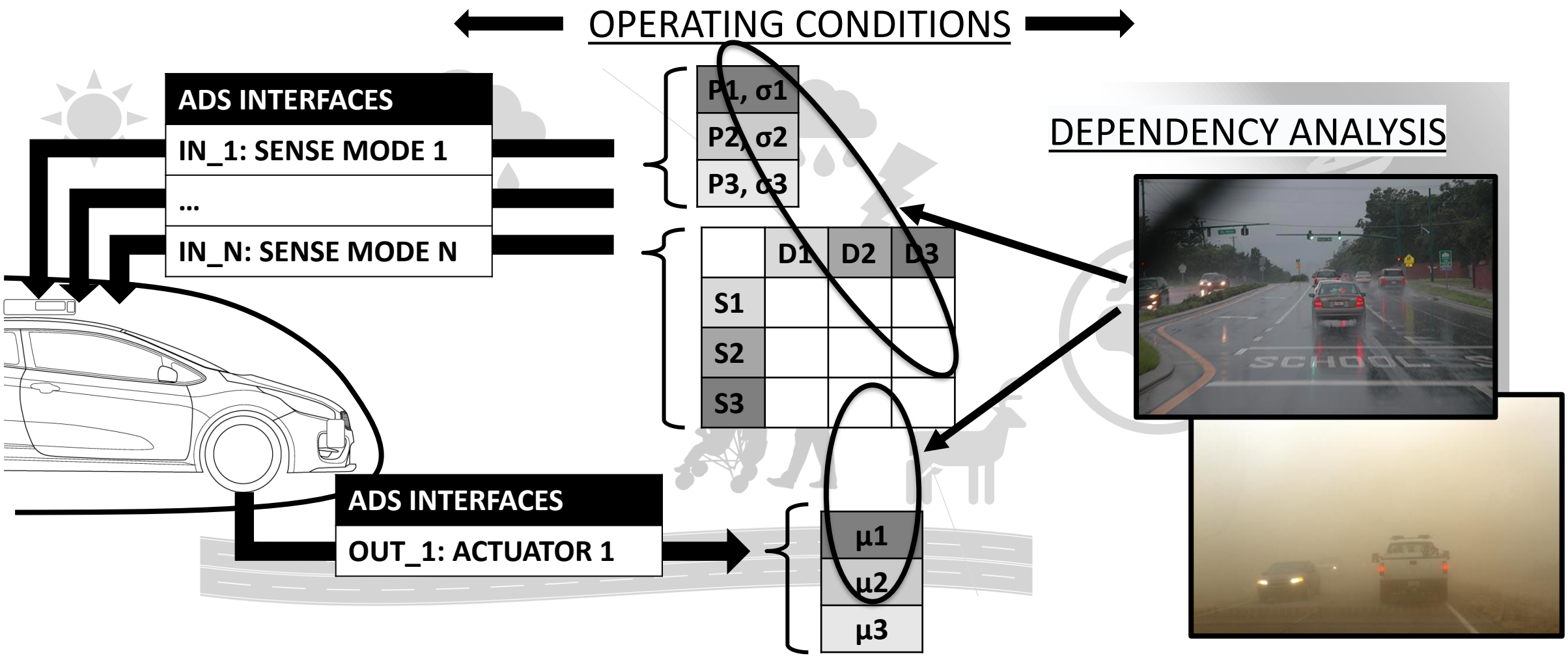
# Sensor-Relevant ODD Classification Framework

# ODD / OC Always Tracing to ADS Interface



# Future Work: Real World Analysis



# Summary

- **ODD Definition for proving performance (e.g. safety) requirements**
- **ODD Definition for sensing modalities**
  - Camera
  - LIDAR
  - Radar
- **Opportunities: Real world analysis**
  - Identifying relevant thresholds
  - Dependent variable analysis
  - Real world data validation

# Thank You

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