SET Level

Simulation-based Development and Testing of Automated Driving

(More) Use Cases for Simulation

Hardi Hungar (DLR)

29.04.2021

Development process*)

SET Level

System & ODD+)

Monitoring

Hazards and risks

Validation

System design

System Integration

Implementation
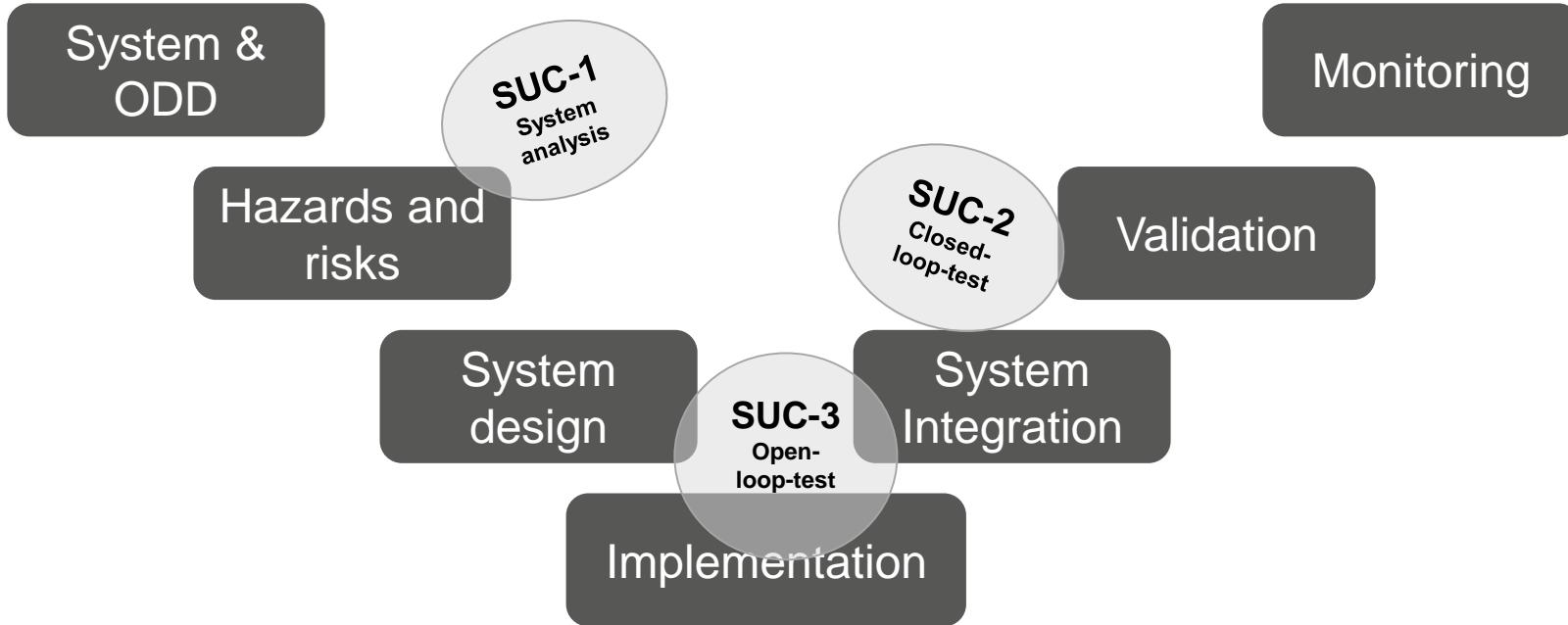
Simulation may serve several purposes in the development of an automated vehicle.

It may be used for analyses, verification, test, validation, and evaluation.

+) **O**perational **D**riving **D**omain

Simulation-based Development and Testing of Automated Driving

Development process and simulation

Simulation use cases (morning session)

System & ODD

SUC-1
System analysis

Monitoring

Hazards and risks

SUC-2
Closed-loop-test

Validation

System design

SUC-3
Open-loop-test

System Integration

Implementation

Simulation may serve several purposes in the development of an automated vehicle.

It may be used for analyses, verification, test, validation, and evaluation.
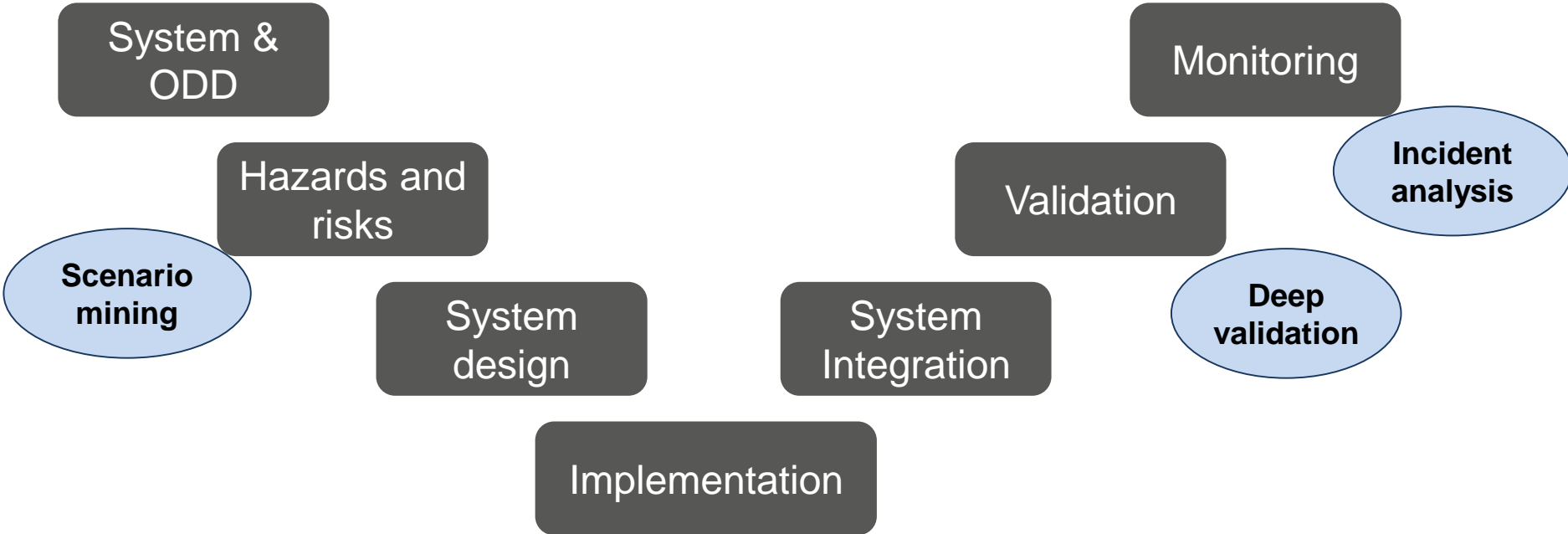
Development process and simulation

(Some) additional use cases

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System &
ODD

Hazards and
risks

Scenario
mining

System
design

Implementation

System
Integration

Validation

Deep
validation

Monitoring

Incident
analysis
```

Simulation may serve several purposes in the development of an automated vehicle.

It may be used for analyses, verification, test, validation, and evaluation.

Simulation Use Case "Scenario mining"

Cover large scenario spaces in search for criticality
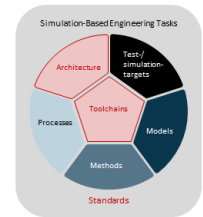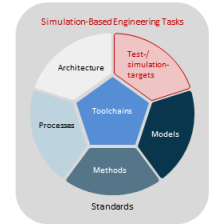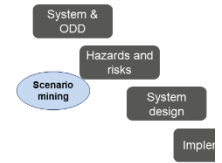
- **Process phase**
  - Hazard and risk analysis

- **Purpose**
  - Discover scenarios to be subjected to a detailed criticality analysis

- **Simulation setup**
  - Combine
    - a traffic flow simulation (SUMO[*)]) to generate a broad range of scenarios
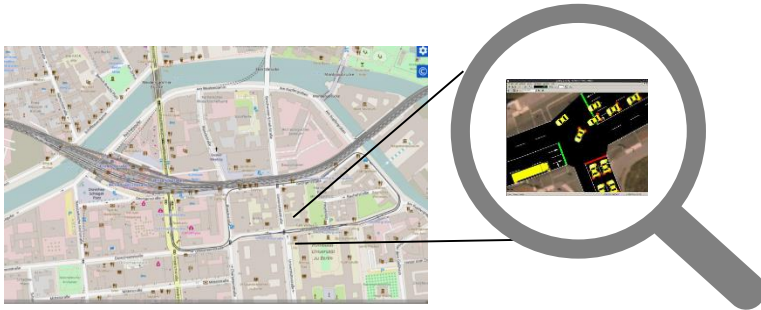   - a detailed simulation (openPASS) to identify critical instances

[*)] **S**imulation of **U**rban **MO**bility, **http://eclipse.org/sumo**

Simulation-based Development and Testing of Automated Driving
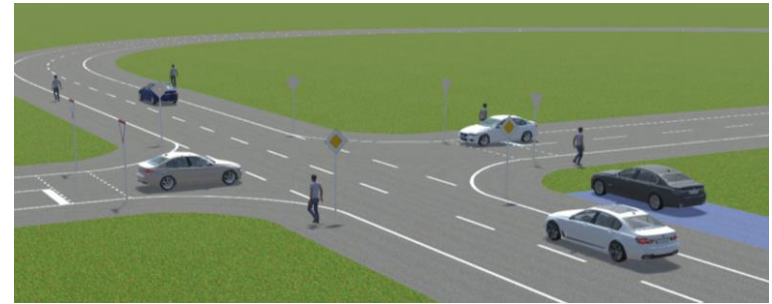
Scenario mining

Realization components

SUMO simulation

- SUMO simulates traffic on a large scale
- Traffic flows can be generated according to variable parameter settings

openPASS simulation

- openPASS simulates detailed scenarios involving a limited number of participants in a specific traffic space (e.g., a crossing)
- It evaluates whether a scenario may turn out critical

Scenario mining

Tool coupling [*under development*]

Simulation-based Development and Testing of Automated Driving
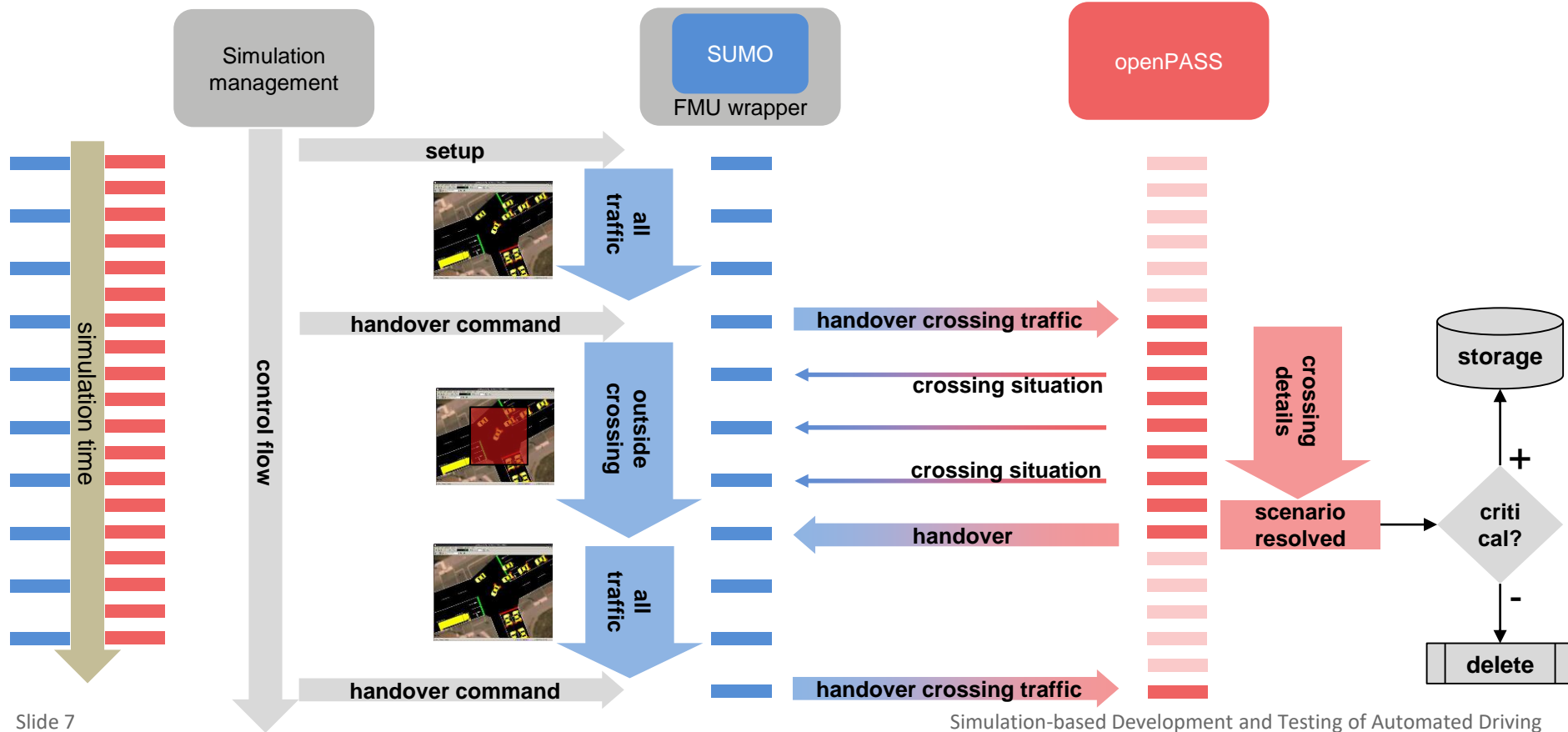
Simulation Use Case "Deep Validation"

Compute the risk

- **Process phase**
  - Validation

- **Purpose**
  - Evaluate the risk of the automated vehicle in traffic

- **Simulation setup**
  - A <u>scenario catalogue</u> covering a specific subset of the ODD
  - A <u>validated model</u> of the automated vehicle (<u>SUT</u>) – sensors, HAD function, vehicle dynamics
  - A credible <u>simulation tool</u>
  - An automated <u>exploration procedure</u> for logical scenarios

Simulation-based Development and Testing of Automated Driving
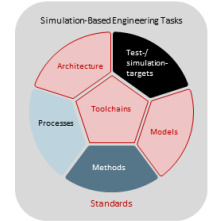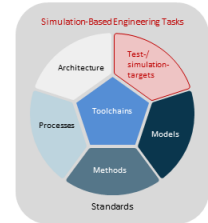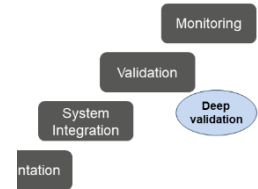
Deep Validation

Computation of risk via systematic scenario exploration

- **Simulation task**
  - Compute the aggregated risk over the concrete instances of a logical scenario

  - **Illustration** on the right:
    - Two scenario variation parameters (*param1* and *param2)*
    - *risk i*s the observed variable, to be measured in single simulation runs
    - To be computed is the volume under the risk function
- **Simulation setup**
 - Closed-loop simulation

Very similar to SUC-2
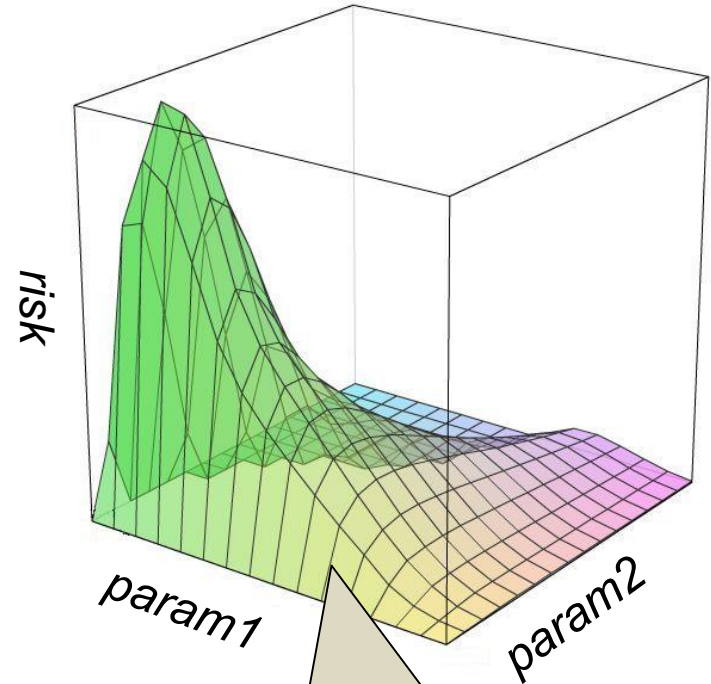
Compute the volume under the risk function graph

Simulation-based Development and Testing of Automated Driving

Deep Validation

Illustration of the systematic scenario exploration

- Computation by <u>approximate discrete summation</u>

  - Like Riemann integral approximation

  - Each <u>column</u> represents the result of a <u>simulation run</u>

  - <u>Lower</u> test <u>density</u> in parameter areas with <u>low risk</u>

> Resembles statistical model checking with importance sampling

risk

param1

param2

> Volume contributed by one run
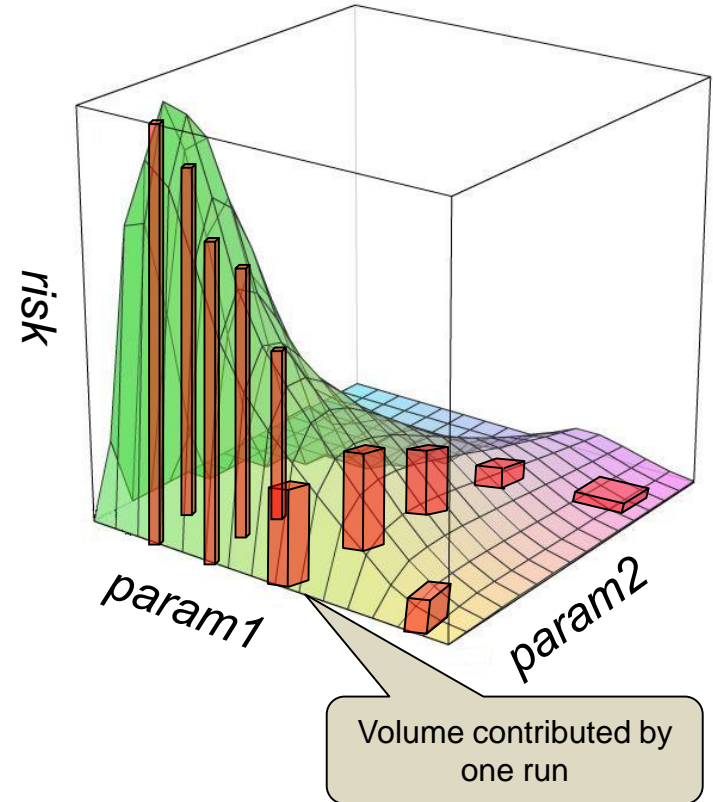
Simulation Use Case "Incident Analysis"

Analyze an incident from system usage

- **Process phase**
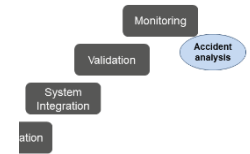 - Monitoring

- **Purpose**
  - Analyze incidents observed by the monitoring function of the automation

- **Simulation setup**
  - Extract a scenario from driving records
  - Generate a representation in OpenSCENARIO/OpenDRIVE for simulation to replay the incident
  - Vary the scenario for a comprehensive analysis

"Replay2Sim"

Simulation-based Development and Testing of Automated Driving
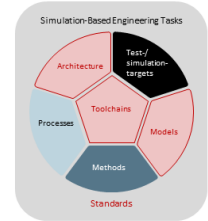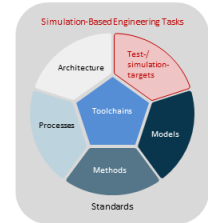
Incident analysis

Detailed procedure

- **Scenario extraction**
  - Use the <u>monitoring functionality</u> of the automated car to detect and record an incident

  Mandatorily available

  automatic

- **Scenario representation**
  - <u>Transform</u> the record to an <u>OpenDRIVE/OpenSCENARIO</u> representation
    - Concrete scenario, trajectory based
    - Use external data sources if available
  - Transform into a maneuver-based, parameterized form

  partly automatic

  Tools under development (not SET Level)

  Concepts under investigation

- **Analysis by simulation**
  - <u>Explore</u> the observed instance and its neighborhood for understanding the incident causes
    - Use SET Level simulation tools and methods
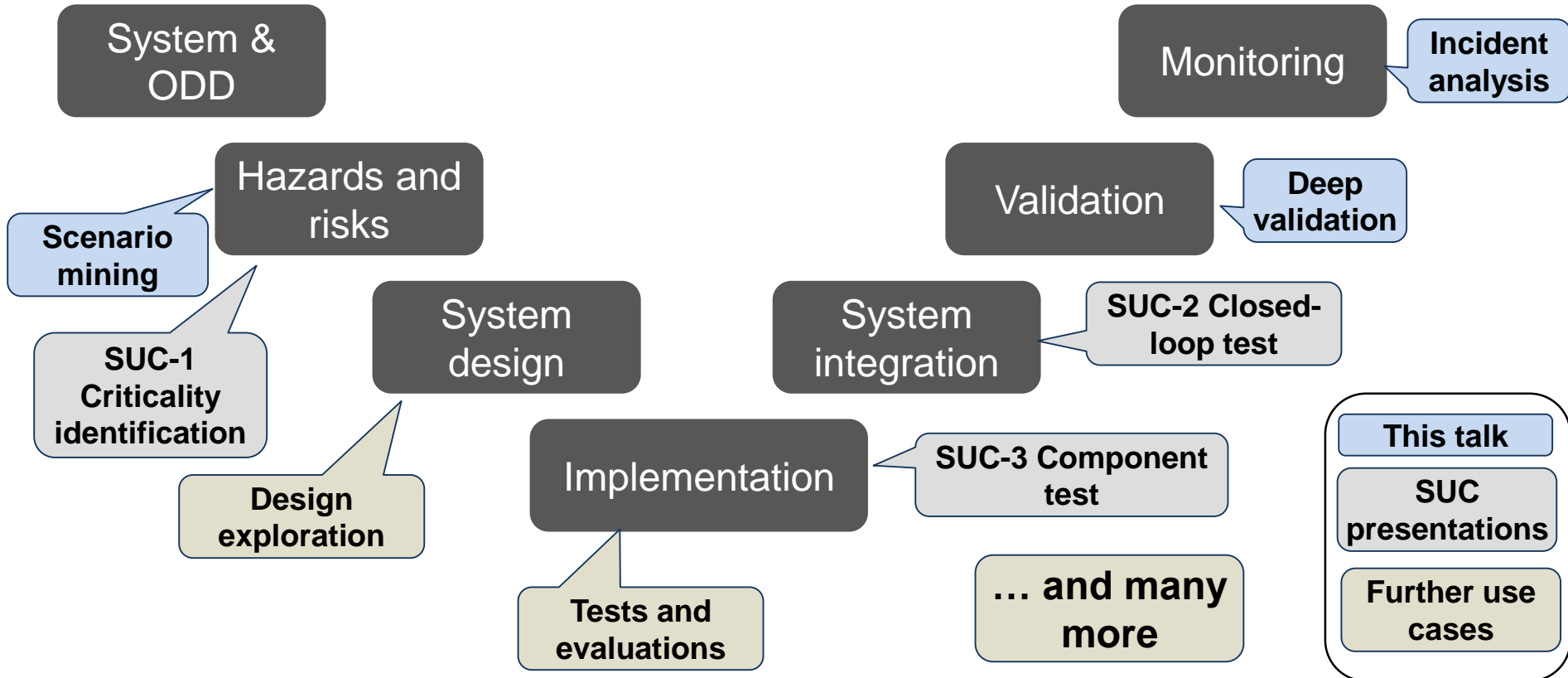
  partly automatic

  Core contribution from SET Level

Summary

A multitude of simulation use cases

Simulation-based Development and Testing of Automated Driving

Summary

Applying SET Level technology

SET Level

- Some of the simulation applications are ready to use

| **Now / at the end of the project** |

| **SUC-1 Criticality identification** | **SUC-2 Closed-loop test** | **SUC-3 Component test** | **Tests and evaluations** | **Scenario mining** |

- Some are easily realized building on SET Level results

| **Design exploration** | **Tests and evaluations** | **… and many more** |

Profit from the open, standard-based, modular approach

- Some are more ambitious (but in some cases already under development)

| **Incident analysis** | **Deep validation** | **… full criticality identification …** |

Build on results, extended in collaborations

Simulation-based Development and Testing of Automated Driving

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