# The Relevance of System Context

## Evaluating Autonomy: What Does “Really Well” Mean?

IROS 2023 Workshop “It Works Really Well!”: Verification in Theory and Practice

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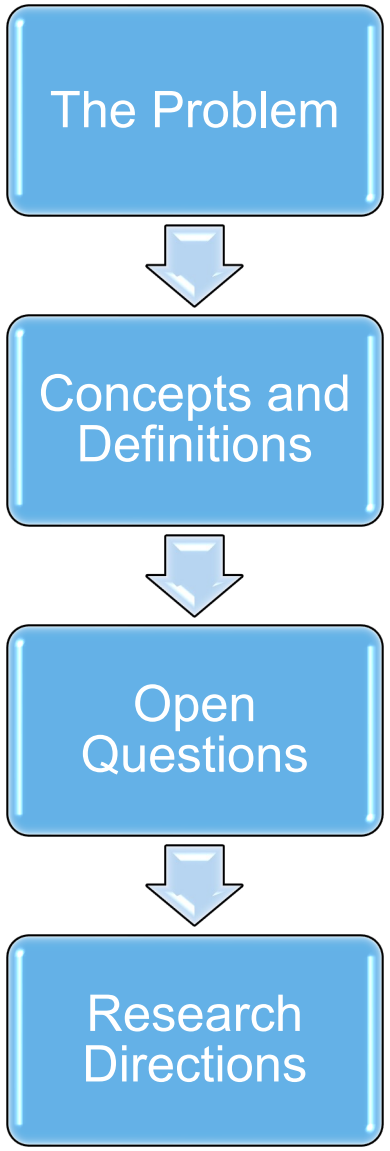
# Overview

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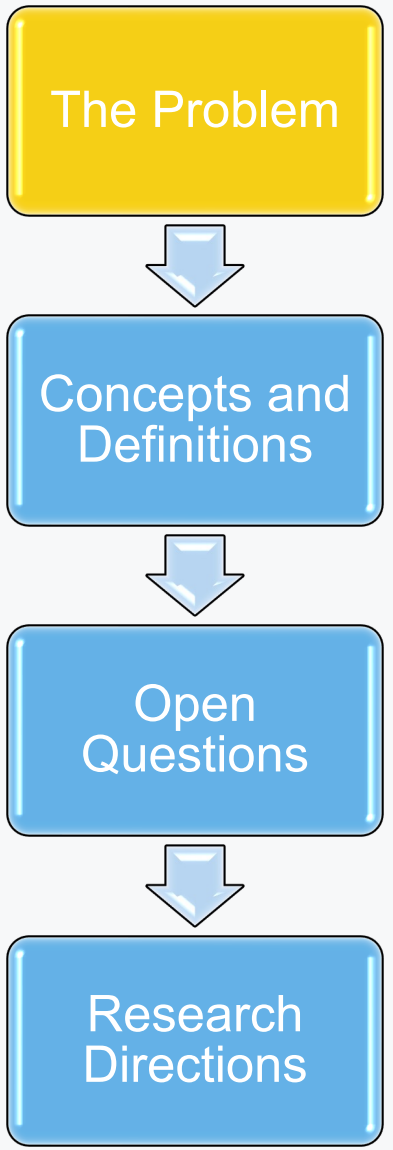
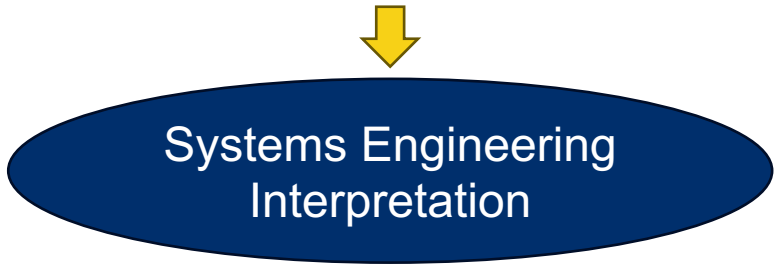
| Requirement | Context 1: Success | Context 2: Failure |
|---|---|---|
| *"The autonomous vehicle must follow all traffic signals"* | Nominal traffic conditions | Emergency situations<br>Construction zone<br>Faulty traffic light |
| *"The autonomous vehicle must halt at all stop signs"* | All stop signs are real | A stop sign shown on a placard |
| *"The cleaning robot must pick all small objects from the floor and throw them away"* | All small objects on the floor are trash | Somebody dropped their keys |
| *"AI must assign more resources to patients who spend more"* | Patients with grave illnesses in a mid to high income bracket | Low income patients |

Context is necessary to define what "Really Well!!" means

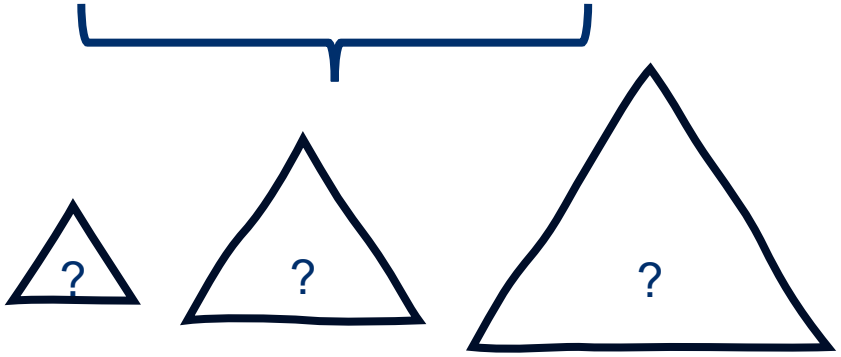


# What happens when context is undefined?

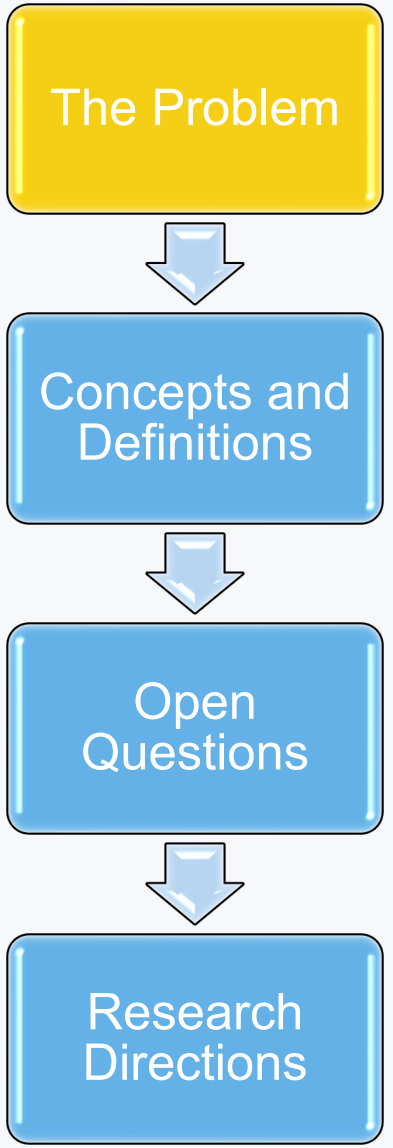
Requirement: *"System must do X"*




*System must do X in all foreseeable situations*



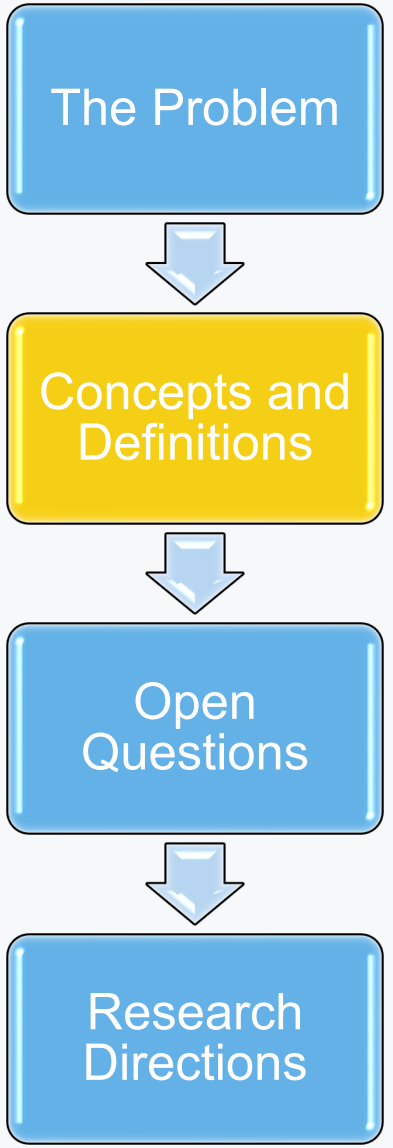

The term "all foreseeable situations" is ambiguously defined making the assurance burden equally unclear!



# Definitions of “Context”

- INCOSE: “The setting in which a system exists, including the stakeholders, system elements, environment, and the relationships among them”
- ISO/IEC/IEEE 15288: “The environment in which a system, product, or service is used or intended to be used”
- “Systems Architecting” (Eberhardt Rechtin): “The broad set of constraints, needs, and goals that shape a system’s requirements, structure, and function”

Existing definitions are too general—not useful for evaluation

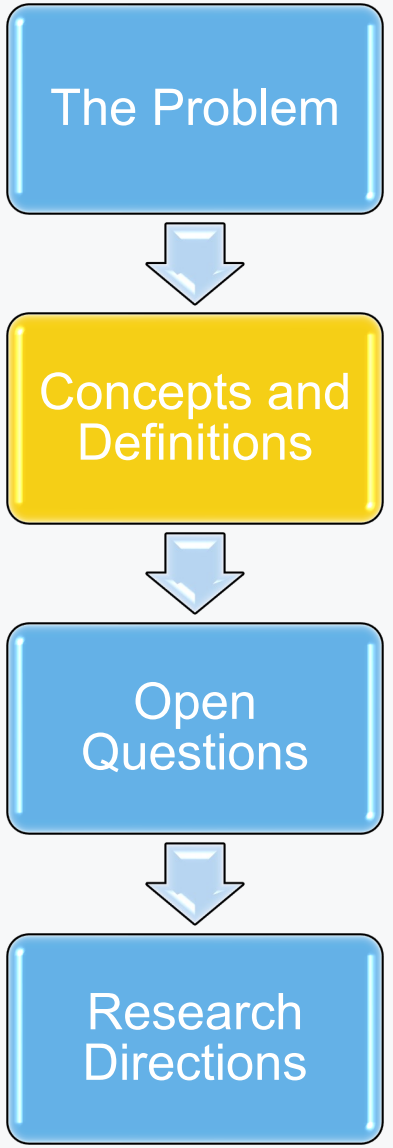


# Operational Design Domains (ODDs)

"Operating conditions under which a given driving automation system or feature thereof is specifically designed to function, including, but not limited to, environmental, geographical, and time-of-day restrictions, and/or the requisite presence or absence of certain traffic or roadway characteristics."

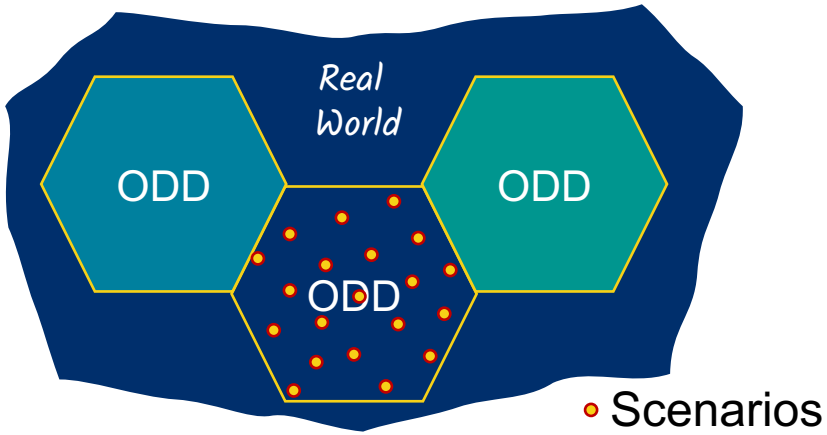
SAE International, J3016 (Apr, 2021): (R) Taxonomy and Definitions for Terms Related to Driving Automation Systems for On-Road Motor Vehicles.

ODDs provide a more concrete approach to defining "context"

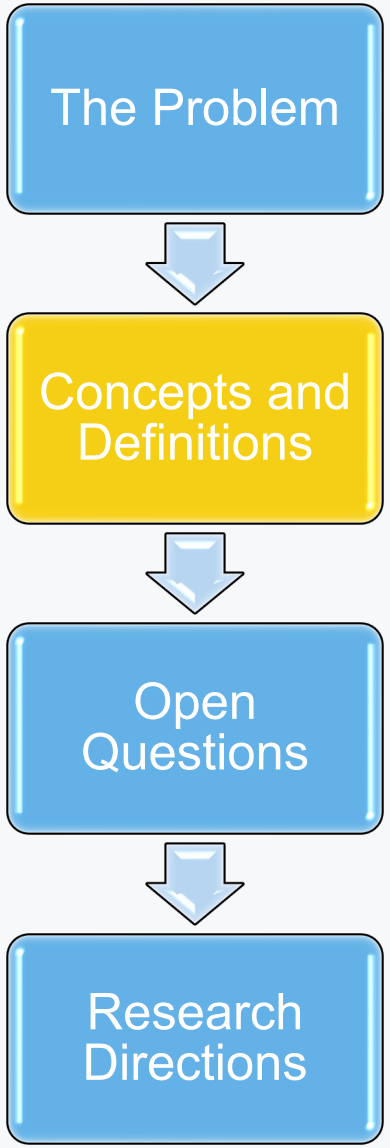


# Related Definitions

- Operational Domain (OD): “real world situations”
- ODD is a model of the OD
- ODD is defined by attributes and their variability
- Scenario:
  - “A description of a driving situation that includes the pertinent actors, environment, objectives and sequences of events” [SOURCE: BSI Flex 1890 v4.0:2022-03, 2.1.73]
  - A unique combination of ODD attributes

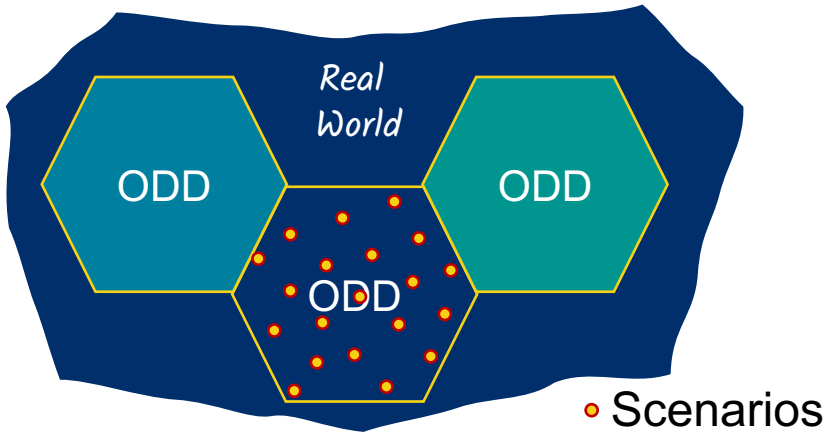


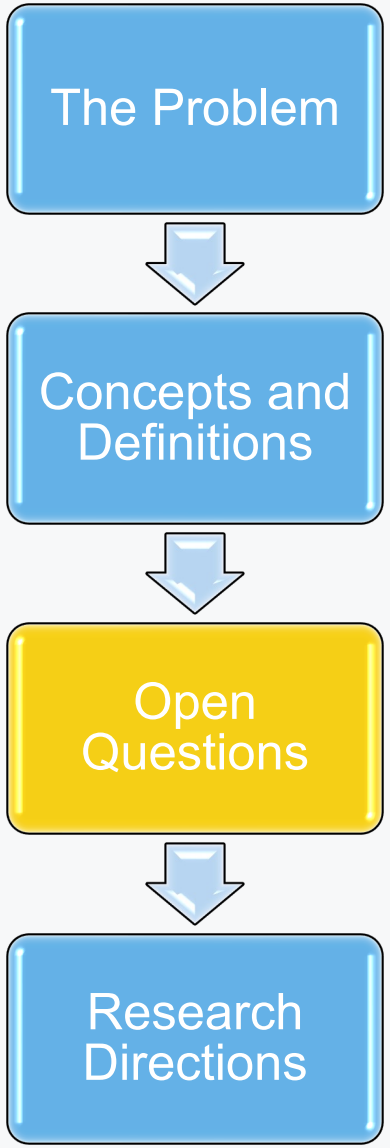

ODDs can be used for scenario-based validation



# 7 Intriguing Questions

1. How do determine how well an ODD covers the OD?
2. How to represent ODDs formally?
   - Examples: OpenScenario, Open-Drive, Scenic, etc.
3. How to define ODD boundaries? How many ODDs?
4. Scenario similarity (“distance”)
5. How many scenarios are sufficient to cover an ODD?
6. What do we do with Δ = OD – ODD?
7. What is the relationship between ODDs and requirements?

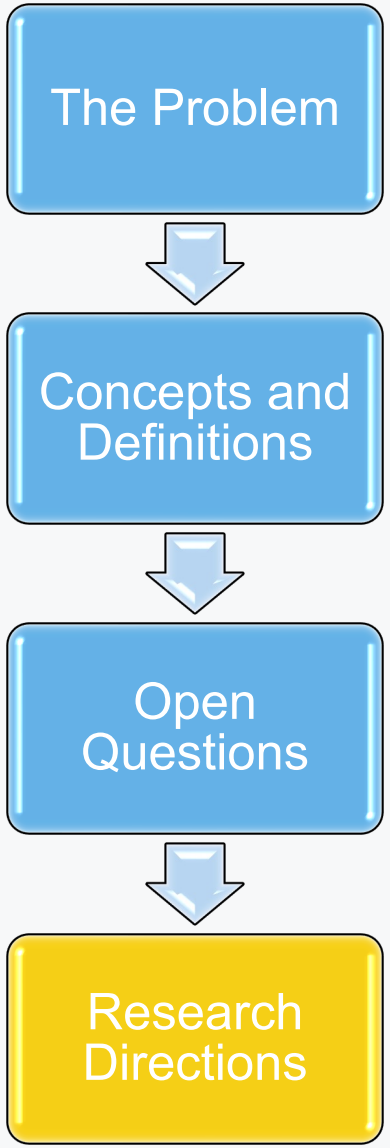


# Research Directions: ODD Description Language (ODD DL)

- Leading scenario description languages are restrictive
  - Need: multi-domain, include adversaries, behavior/intent, etc.
- Use description language to automatically generate “knobs” and “probes” for external simulators (scenario-based sim-based testing)
- Use ODD DL description language to generate scenarios automatically
- Experiments in generating ODD DL from natural language via LLMs
- Experiments in interpretation of ODD DL as probabilistic programming languages
- Complementary with work in requirement formalization and test generation from requirements

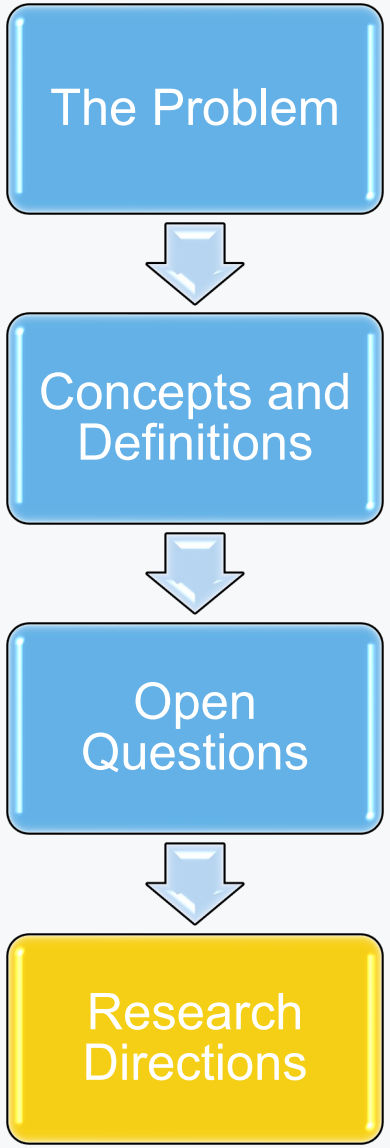
ODD DLs have opened rich and impactful lines of research



# Research Directions: Assurance

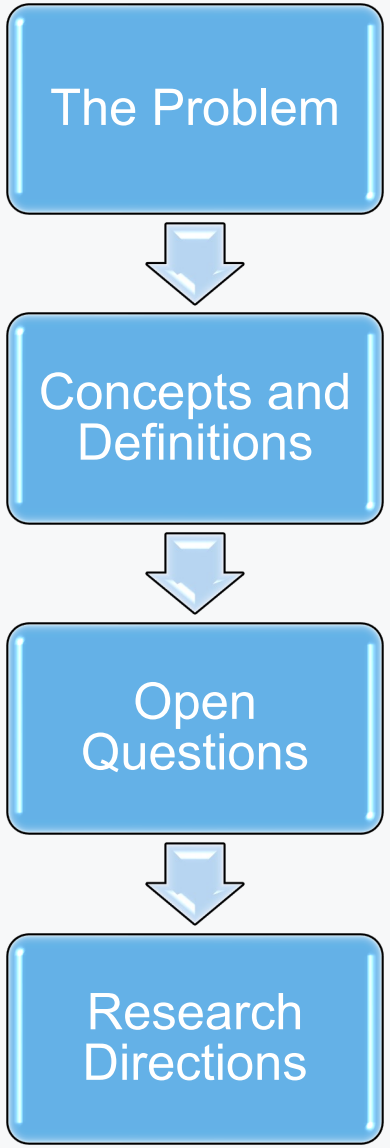
- Assurance case patterns for scenario-based validation
  - Real world coverage: $\bigcup_i ODD_i \sim \text{Real World}$
  - OD Coverage ($ODD_i$ description is representative)
  - Scenario Coverage (Scenario samples cover $ODD_i$)
  - Fidelity (Validation environment produces valid executions)
- Agile assurance
  - It is easier to achieve justified confidence if we restrict ODD's variability or the scope of the real world (# ODDs)
  - Automation for assurance case regeneration when context changes
- Semantic reasoning
  - Can we reuse evidence or assurance case fragments based on context similarity?

Reasoning about context opens the possibility for meaningful integration of assurance and agility!



# Conclusions

- There is important work in relation to context that will help with the deployment of autonomous systems with justified confidence
- We need to leverage the groundwork laid by the autonomous driving community, e.g.: ODDs, scenario-based validation, etc.
- Reasoning about context could serve as the basis for the introduction of agility in assurance
- Context size ∝ Assurance burden




"Really Well" only makes sense if we specify context formally and rigorously

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