Assurance Strategies for Safe AI Operation: Model-based Framework for the Development, Simulation and Monitoring of ODD

Christoph Torens*[1], Siddhartha Gupta[1]

[1]Deutsches Zentrum für Luft- und Raumfahrt (DLR), Institute of Flight Systems
*Christoph.Torens@dlr.de

1. Challenge: Safe AI Operation

- Significant demand for AI, e.g., vision-based tasks to support the landing operation
- New technology: AI behavior defined by training data
- Mismatch between existing certification standards and AI development paradigm
- EASA recommends defining the operational conditions and use it to train and certify AI systems

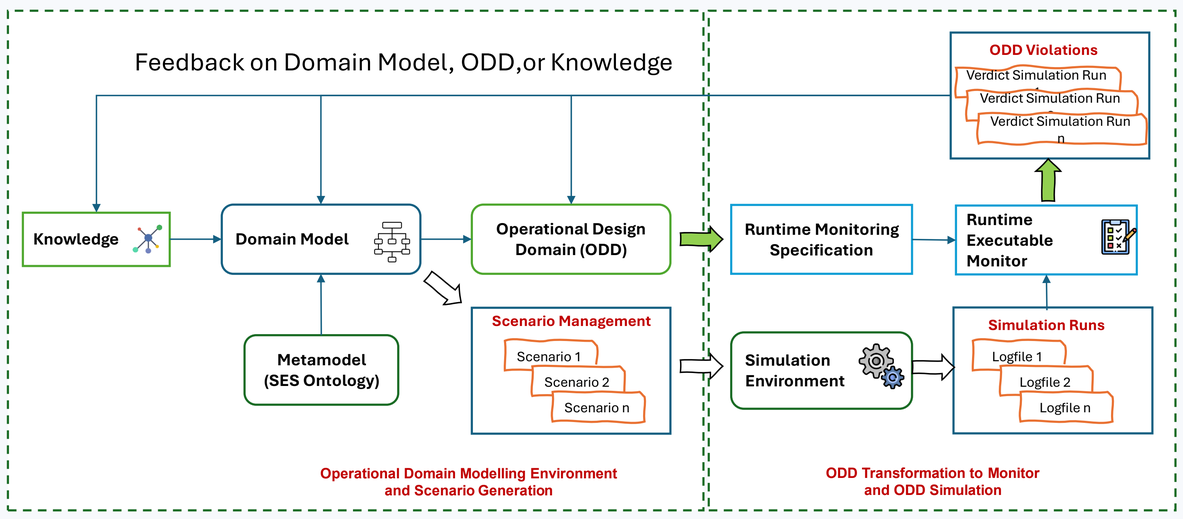
Certification guidance

- Mandatory supervision of the environmental conditions during operation
- Check if operating conditions match training distribution

2. Operational Design Domain (ODD)

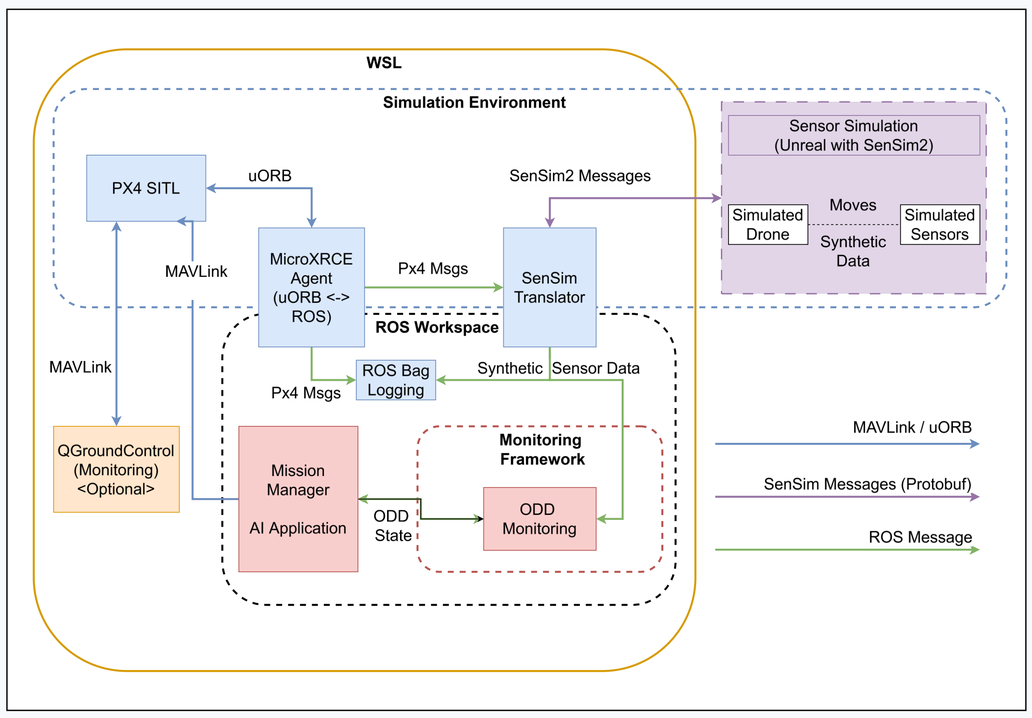
- ODD formalizes the allowed environmental and operating conditions
- Allows to explicitly state operational constraints, e.g., operation at daytime (10 am to 2 pm)
- Enabled safety assurance for AI component
- Parameters depend on AI component
- Possible parameters include:
  - Allowed altitude range
  - Lighting conditions
  - Weather effects: rain, snow, fog
  - Geofence

3. Model-based ODD Framework



Overview of the model-based ODD framework. The first goal is to generate scenarios within and on the edges of the ODD, as well as evaluating the coverage of the scenarios. The second goal is to build a monitoring solution that can supervise the ODD and its properties. These goals are combined with the simulation framework SenSim2, which our Institute develops.

4. Simulation and Monitoring Framework



Architecture of the simulation and monitoring framework. SenSim2 utilizes the Unreal Engine 5 runs natively on a Windows computer, ROS2 is run via the Windows Subsystem for Linux (WSL). Any data from ROS2 and SenSim2 is forwarded to the monitoring framework.

5. Simulation of ODD

Simulation of different ODD parameters utilizing the SenSim2 framework. Simulation is based on Unreal Engine 5 and can simulate daylight conditions, rain, snow and fog. The simulation framework is also capable of simulating additional sensors, such as Lidar.

6. Holistic ODD Approach, Closing the ODD Loop

- Enables formal modeling of domain
- Model-based extraction and refinement of ODD
- ODD drives scenario modelling and monitoring specifications
- Model transformation, e.g., into ASAM OpenODD standard
- ODD monitoring during simulation run
- Closing the loop from ODD simulation to refinement

Vision and Goals

- Scenario generation and simulation to achieve full ODD coverage
- Supervision of AI system operational requirements
- Gain insights into ODD concept
- Toolchain for refinement of ODD parameters
- Enabling ODD constrained operation

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More Information: **From Operational Design Domain to Runtime Monitoring of AI-Based Aviation Systems**
Torens, Christoph and Gupta, Siddhartha and Roy, Nirmal and Sprockhoff, Jasper and Durak, Umut (2024)
In: AIAA DATC/IEEE 43rd Digital Avionics Systems Conference (DASC), 2024-09-29 - 2024-10-03, San Diego. https://doi.org/10.1109/DASC62030.2024.10749267 ISBN 979-835034961-0. ISSN 2155-7195.

More Information: **Runtime Monitoring of Operational Design Domain to Safeguard Machine Learning Components**
Torens, Christoph and Juenger, Franz and Schirmer, Sebastian, and Nagarajan, Pranav, and Schopferer, Simon and Zhukov, Dmytro and Dauer, Johann
In: CEAS Aeronautical Journal 16, 973–991 (2025).
https://doi.org/10.1007/s13272-025-00883-6

DGLR German Society for Aeronautics and Astronautics Lilienthal-Oberth e.V.
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