

# Kaan Akgün

## AI & Autonomous Systems Portfolio

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### 1. Executive Summary & Tech Stack

**Software Engineer** with over 7 years of experience in **Safety-Critical AI** and **Autonomous Systems**, holding a Master's degree. Specialized in developing safe AI architectures in compliance with EASA aviation regulations and ISO 26262 standards. Adopts a research-oriented engineering approach with **10+ open-source projects** on GitHub and active community contributions.

**AI & Data**   LangChain   RAG Pipelines   PyTorch   ONNX   LLM Agents   Pandas

**Systems**   ROS 2   Kubernetes   Docker   Kafka   Linux   WebAssembly

**Safety**   ISO 26262   SOTIF   EASA Regs   MDD / ODD   Entity Structure

### Portfolio Navigation

*This document is organized into interactive sections for a detailed review of my work.*

- **Section 2: Academic Research & Commercial Ventures**

Thesis, Publications, Projects, and Startup.

- **Section 3: Technical Projects (GitHub Repositories)**

AI Pipelines, Autonomous Driving, System Architectures.

- **Section 4: Medium Articles & Industry Analysis**

Parallel Computing, Cybersecurity, and Deployment Strategies.

- **Section 5: Certificates & Achievements**

Specializations, trainings, and course certificates.

- **Section 6: Detailed Abstracts of Academic Work**



Extended technical abstracts of thesis and papers.

- **Section 7: Visual Portfolio & Diagrams**

Project architectures, flowcharts, and prototype visuals.



# Master Thesis: Model-Driven Development of ODD for AI Based Systems

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Problem	The aviation industry is integrating AI-based autonomous systems, but ensuring safety is difficult. EASA regulations require a strict <b>Operational Design Domain (ODD)</b> —the specific environment (weather, geography) where AI is safe. Currently, ODD modeling is often disconnected from the actual testing process, creating safety gaps.
Limitations	Traditional Model-Driven Development (MDD) lacks automated integration of ODD constraints. Scenario generation is often manual, leading to fragmented testing, and the resulting data is too bulky for high-frequency automated simulation.
My Solution	<p>I introduced the <b>Partial Pruning Entity Structure (PPES)</b> as a vital architectural layer.</p> <ol style="list-style-type: none"><li>1. <b>Integration:</b> Embedded ODD parameters directly into the scenario generation logic.</li><li>2. <b>Optimization:</b> Implemented <b>Protocol Buffers (Protobuf)</b> to convert scenario data into a binary format, maintaining 60% integrity while drastically reducing data size.</li><li>3. <b>Validation:</b> Successfully created an automated, verifiable test environment for drone systems.</li></ol> <p> <a href="#">Read Detailed Abstract</a>    <a href="#">View Architecture</a></p>



## Project: Automated Method for Pruning System Entity Structures (SES)

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Problem	Flight simulation scenarios rely on SES ontologies to manage system components. As systems grow more complex, managing these ontologies manually becomes impossible, leading to modeling errors and inconsistent test results.
Limitations	Existing pruning methods (selecting model branches) were manual and slow. This limited scenario diversity and made it difficult to generate precise, criteria-driven simulation models required for aviation research.
My Solution	<p>Developed an innovative <b>Automated SES Pruning Algorithm</b>.</p> <ol style="list-style-type: none"><li>1. <b>Ontology Mapping:</b> Identified all widget components and structural relationships within the high-level SES framework.</li><li>2. <b>Logic Automation:</b> Built a mechanism that automatically selects model branches based on predefined test criteria.</li><li>3. <b>Speed:</b> Accelerated the scenario generation pipeline, enabling rapid, error-free model creation for complex flight simulations.</li></ol> <p> <a href="#">Read Detailed Abstract</a>    <a href="#">View Flow Diagram</a></p>

## Publication: Critical Scenario Techniques for Automated Vehicles

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Problem	Validating Automated Driving Systems (ADS) by simply driving millions of miles is statistically insufficient. Critical "edge cases" (near-misses or rare accidents) occur too infrequently in normal driving to prove a system is truly safe.
Limitations	Current simulation tests often focus on routine driving. There was no systematized methodology to mathematically identify and prioritize which scenarios are "critical" enough to warrant testing.
My Solution	<p>Conducted a <b>Methodological Synthesis</b> to systematize critical scenario analysis.</p> <ol style="list-style-type: none"><li>1. <b>Taxonomy:</b> Classified scenario types based on safety impact and environmental complexity.</li><li>2. <b>Quantification:</b> Analyzed techniques for mathematically prioritizing the most dangerous situations for ADS testing.</li><li>3. <b>Risk-Oriented Framework:</b> Proposed a roadmap for focusing verification on human-error scenarios, reducing real-world accident frequency.</li></ol> <p> <a href="#">Read Detailed Abstract</a>    <a href="#">View Taxonomy</a></p>

## Startup: Control of Long-Distance UAVs Using DTMF on GSM

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- Problem** Civilian and military UAVs suffer from range limitations. Standard radio controls (Line-of-Sight) have a very short range, while satellite-based systems are prohibitively expensive and complex for most lean startups.
- Limitations** Existing long-range systems require massive infrastructure and high-power transmitters, making them bulky, expensive, and difficult to deploy in flexible missions.
- My Solution** Engineered a **Lean Control System** leveraging global GSM networks and DTMF signals.
1. **Infinite Range:** Used mobile networks to eliminate geographical distance constraints between the pilot and the UAV.
  2. **Signal Processing:** Implemented **Dual Tone Multi Frequency (DTMF)** to send robust control commands over voice channels.
  3. **Lean Integration:** Created a lightweight, low-cost unit that provides a reliable alternative to satellite links.

 [Read Detailed Abstract](#)    [View Prototype](#)

### 3. Technical Projects (GitHub Repositories)

#### About the STAR Method:

This portfolio utilizes the **STAR** method—a structured storytelling technique favored by industry leaders like Amazon—to present technical achievements with clarity and impact. This approach ensures every project is defined by its engineering challenges and measurable results:

- Situation** The specific technical challenge, constraint, or industrial context faced.
- Task** The defined objective or the exact problem that needed to be addressed.
- Action** The technical execution, including the specific architectures and tools developed.
- Result** The tangible, quantifiable outcome and the strategic value added to the project.

[Amazon STAR Method](#)

## AI & LLM Pipelines

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### 🕒 Autonomous Safety Constraint Validation

ASCV-GenAI

**Situation:** Manual safety rule extraction from dense EASA aviation regulatory documents was labor-intensive, slow, and prone to human interpretation errors.

**Task:** Automate the safety constraint validation process to ensure that AI-based systems comply with aviation certification requirements during the development lifecycle.

**Action:** Architected a high-performance RAG (Retrieval-Augmented Generation) pipeline using Llama 3 and LangChain, deployed on a GPU-accelerated Kubernetes cluster to parse and verify constraints against system models.

**Result:** Achieved an 80% reduction in rule definition time while increasing the consistency of safety compliance audits for autonomous flight software.

 [View Diagram \(Sec 7\)](#)

### 🕒 AI Research Pipeline

AI-Research

**Situation:** The exponential growth of AI research papers made it impossible for engineers to manually track relevant breakthroughs, leading to significant information overhead.

**Task:** Design an autonomous research agent capable of identifying, analyzing, and summarizing top-tier technical papers to streamline R&D workflows.

**Action:** Developed an end-to-end automation pipeline utilizing n8n for orchestration, Groq for ultra-fast LLM inference, and FastAPI to serve real-time summaries to research teams.

**Result:** Fully automated the daily literature review process, reducing time spent on manual screening by 10+ hours per week.

 [View Diagram \(Sec 7\)](#)

### 🕒 LLM Optimization Analyzer

Optimization

**Situation:** Large Language Models often exceed the memory and latency limits of edge computing devices used in autonomous vehicles and robotics.

**Task:** Create a framework to analyze the trade-off between model inference speed and output accuracy across various quantization levels (INT8, FP16).

**Action:** Built a comprehensive optimization analyzer using ONNX Runtime to automate benchmarking and model conversion for target hardware platforms.

**Result:** Enabled data-driven deployment decisions, achieving a 3x speedup in inference while maintaining a 98% accuracy threshold.

 [View Diagram \(Sec 7\)](#)

## NLPCon- verter

**Situation:** Operational Design Domain (ODD) definitions are typically written in unstructured natural language, making them impossible to load into simulation engines.

**Task:** Develop a robust translation layer to convert human-readable safety requirements into structured, machine-executable YAML configurations.

**Action:** Engineered a specialized parser using advanced NLP techniques and Python dataclasses to map semantic environmental constraints to a validated schema.

**Result:** Enabled seamless integration between regulatory documentation and automated simulators, allowing text-based ODDs to be executed as test cases instantly.

 [View Diagram \(Sec 7\)](#)

## Autonomous Driving & Safety

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### autoVal- SLAM

**Situation:** Sharing SLAM research typically requires complex local environment setups (ROS, dependencies), which hinders quick collaboration and demos.

**Task:** Provide a platform-agnostic, zero-installation demonstration tool for visualizing LiDAR-based mapping algorithms to stakeholders.

**Action:** Ported core Python LiDAR processing and SLAM logic to WebAssembly (Wasm) using the Pyodide framework, allowing high-performance computation in the browser.

**Result:** Achieved a functional, zero-setup SLAM simulation running directly in the browser, improving research accessibility and demo efficiency.

 [View Diagram \(Sec 7\)](#)

### Safety PoC

#### RISC-V Automotive Safety

**Situation:** AI System-on-Chips in autonomous vehicles require strict hardware-level isolation to prevent non-safety tasks from interfering with critical functions.

**Task:** Build a hardware-software Proof-of-Concept for ASIL-D fault isolation using the open-source RISC-V architecture.

**Action:** Configured RISC-V Physical Memory Protection (PMP) units and developed a Real-Time Fault Manager to monitor and isolate illegal memory accesses.

**Result:** Proven effective hardware-level isolation of safety-critical processes, meeting the core requirements of the ISO 26262 automotive standard.

 [View Diagram \(Sec 7\)](#)

### ODD Extract

**Situation:** The NuScenes dataset contains massive raw sensor data but lacks structured ODD metadata needed for automated, scenario-based safety testing.

**Task:** Automate the extraction of environmental parameters (weather, traffic density) from raw sensor logs and dataset headers.

**Action:** Developed a data-mining algorithm that maps raw data signatures to a formalized System Entity Structure (SES) ontology for precise categorization.

**Result:** Generated high-fidelity ODD metadata for thousands of data frames, enabling automated edge-case test scenario generation.

 [View Diagram \(Sec 7\)](#)

## Synthetic ODD Synthetic ODD Data Generation

**Situation:** Training autonomous driving models requires vast amounts of "edge case" data, which is rare and dangerous to collect in real-world environments.

**Task:** Design a generator to produce statistically valid synthetic ODD data points representing rare and critical environmental conditions.

**Action:** Built a generator based on statistical outlier distributions to create corner-case scenarios (e.g., extreme visibility loss combined with sensor noise).

**Result:** Improved model robustness by 15% in rare-event simulations by providing targeted synthetic training sets for deep learning models.

 [View Diagram \(Sec 7\)](#)

## Systems & Software Architecture

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### Observability Gateway

Observability

**Situation:** Monitoring high-throughput, low-latency microservices using traditional tools often introduces unacceptable performance overhead on the request path.

**Task:** Establish a centralized observability gateway capable of distributed tracing and metrics collection with minimal impact on latency.

**Action:** Developed a custom gateway using Rust and the Tokio async runtime, integrating OpenTelemetry (OTEL) and Prometheus for high-performance monitoring.

**Result:** Achieved full system observability with sub-millisecond impact on request latency, ensuring 24/7 reliability for mission-critical services.

 [View Diagram \(Sec 7\)](#)

### ODD Pipeline

**Situation:** Managing real-time ODD data streams for a fleet of autonomous vehicles requires a highly scalable architecture to avoid data loss during peak loads.

**Task:** Design a scalable processing pipeline to ingest and store millions of environmental data points per hour from distributed vehicle sensors.

**Action:** Built a distributed data pipeline using Apache Kafka for streaming, Redis for hot caching, and Cassandra for persistent storage of high-frequency data.

**Result:** Ensured 99.99% data integrity and sub-second processing latency for large-scale environmental monitoring systems.

 [View Diagram \(Sec 7\)](#)

### Robotics Smart Factory ROS Demo

**Situation:** Robotics simulations are notoriously difficult to port across different hardware, leading to inconsistent results and "works on my machine" issues.

**Task:** Create a standardized, portable, and cloud-native simulation environment for a Smart Factory robotics project.

**Action:** Dockerized ROS2 Humble and Gazebo Ignition, and orchestrated deployment to a Kubernetes cluster using GPU-accelerated nodes and Helm charts.

**Result:** Reduced developer environment setup time from days to minutes, providing consistent "Simulation-as-a-Service" for the team.

 [View Diagram \(Sec 7\)](#)

## Geo-AI PulseView

**Situation:** Manual analysis of high-resolution satellite imagery for urban change detection is slow, expensive, and prone to human oversight.

**Task:** Automate the detection of geographic and structural changes over time using computer vision and satellite data feeds.

**Action:** Integrated an AI-powered change detection engine with a custom React-based GIS interface to visualize urban growth and environmental shifts.

**Result:** Drastically accelerated geographic monitoring, enabling near real-time detection of illegal constructions and urban changes.

 [View Diagram \(Sec 7\)](#)

## ScenarioForge

ScenarioForge

**Situation:** Test scenarios used in simulations were often stored in scattered, unversioned files, leading to consistency issues and duplicated effort.

**Task:** Develop a centralized, version-controlled repository to manage and serve simulation scenarios via a standardized API.

**Action:** Built a RESTful backend service using Spring Boot and PostgreSQL, featuring version control and metadata search for YAML-based scenarios.

**Result:** Established a "Single Source of Truth" for testing, ensuring all simulation pipelines use validated and consistent scenario versions.

 [View Diagram \(Sec 7\)](#)

## GreenChain (SAP BTP)

GreenChain

**Situation:** Standard SAP ERP systems do not natively provide the granularity needed to track supplier ESG scores in real-time during procurement.

**Task:** Integrate sustainability metrics directly into the SAP S/4HANA procurement workflow to empower ethical purchasing decisions.

**Action:** Developed a Cloud Application Programming (CAP) module on SAP BTP to fetch, analyze, and display supplier ESG scores within the ERP interface.

**Result:** Enabled data-driven sustainable procurement, allowing teams to prioritize suppliers with the best environmental and social performance.

 [View Diagram \(Sec 7\)](#)

## Pose Est. Pose Estimation PoC

**Situation:** 3D coordinate transformations and pose estimation are computationally heavy and critical for accurate robotic arm manipulation.

**Task:** Build a high-performance math engine for 3D transformations from scratch to optimize robotic vision latency.

**Action:** Implemented a core 3D transformation engine in C++ using the Eigen library, focusing on Quaternion-based rotations and Euler conversions.

**Result:** Provided a highly optimized mathematical foundation for low-latency pose estimation, essential for real-time robotic interaction.

 [View Diagram \(Sec 7\)](#)

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## 4. Medium Articles & Industry Analysis

Article **The Power of Parallel and Distributed Computing**

Date Jun 4, 2024

Summary A technical analysis on the importance of the shift from sequential processing to parallel and distributed architectures in modern high-performance systems. Examines the critical role of distributed computing on scalability.

 [Read on Medium](#)

Article **Don't Fear the Chocolatey Bar: Mastering Windows Pkg Mgmt.**

Date Dec 23, 2023

Summary Using the Chocolatey package manager to automate software management in Windows environments. A guide on secure, reproducible installations and package standardization in DevOps processes.

 [Read on Medium](#)

Article **The Inaudible Trojan That Exploits Your Devices**

Date Jun 30, 2023

Summary Analysis of next-generation cybersecurity threats targeting voice assistants. Discusses audio processing vulnerabilities in IoT devices and attack vectors using frequencies inaudible to the human ear.

 [Read on Medium](#)

Article **Einführung in Deployment-Strategien: Blau-Grün & Canary**

Date Jun 30, 2023

Summary A comprehensive technical review of modern software deployment strategies (Blue-Green, Canary, Rolling Update). Best practices in CI/CD processes and risk minimization methods based on organizational needs.

 [Read on Medium](#)

## 5. Certificates & Achievements

**Overview** *To maintain a broad and versatile perspective across different technological domains, I have acquired a diverse range of certifications spanning from SAP and Google Cloud to AI and Network Administration. Additionally, my background in competitive chess strengthens my strategic and analytical approach to engineering.*

### Achievements

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**20+ Years Competitive Chess Player | Turkish Chess Federation & FIDE**  
**Summary** Participated in nearly **100+ local, national (Turkish Chess Federation), and international tournaments**. Achieved numerous successes.  
**FIDE ID** [🔗 Official FIDE Profile: 6301363 \(View Ratings\)](#)

### Academic Certification

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**2022 Self-editing PhD Level Writing | Clausthal University of Technology**

### Google Cloud & Generative AI

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**2025 MLOps & Vertex AI:** Model Evaluation and Generative AI Operations  
**2025 Cloud Infrastructure:** Kubernetes (GKE) and Terraform Management  
**2023 GenAI Fundamentals:** Transformer Models, BERT, and Attention Mechanisms

### SAP Business Technology Platform & ERP

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**2025 SAP Build & HANA:** Automated build processes and ML clients for HANA  
**2025 SAP BTP:** Cloud Application Programming (CAP), DevOps, and ABAP Environment

## 6. Detailed Abstracts of Academic Work

### Master Thesis: Model Driven Development of Operational Design Domain for AI Based Systems

The aviation industry is undergoing a major transformation through the adoption of Artificial Intelligence (AI). Current AI-based systems in the aviation domain offer a promising alternative by enabling simulations that ensure safety compliance; however, they also highlight the need for regulations established by authorities such as the European Union Aviation Safety Agency (EASA). The concept of The Operational Design Domain (ODD) is used to ensure safe operations of the AI-based autonomous systems. ODD specifies the precise operating conditions, such as environmental, geographical, and performance parameters, under which an AI-based system is intended to function safely. Model-driven development (MDD) provides a practical approach to simulate operational scenarios and system interactions, allowing users to assess AI-based systems under realistic conditions.

The Informatics department of TU Clausthal developed a tool called Operation Domain Modeling Environment (ODME) tool for modeling complex systems using System Entity Structure (SES) in the MDD approach. The SES framework, a hierarchical modeling approach that organizes system components, their attributes, and relationships in a structured manner, enables efficient pruning and scenario generation. The SES framework in the tool allows modeling pruning of the model to create Pruned Entity Structure (PES), generate specific executable scenario models, and specify the ODD of the modeled system.

Generating numerous scenario models is error-prone, emphasizing the need for automation. ODD is decoupled in the current MDD approach, which complicates the preparation for the automated scenario generation process. Integrating ODD into scenario generation enhances scenario diversity evaluation and ensures parameter coverage. Furthermore, data output should be optimized for the size of the data while maintaining integrity and consistency for the automated scenario generation process.

In this thesis, the Partial Pruning Entity Structure (PPES) is introduced as an intermediate layer between SES and PES to enhance the preparation of an automated scenario generation process in MDD by integrating ODD into the scenario generation process. PPES, a refinement approach, organizes model components by eliminating redundant entities and optimizing the variables of the entities. The option of converting from text to binary format using Protocol Buffers (Protobuf) serves as an alternative to meet the requirements of this process.

The case study within the drone domain model demonstrates that PPES facilitates the preparation of an automated scenario generation process, and Protobuf ensures data integrity while reducing data size.

Overall, the proposed framework integrates realistic operational constraints into a structured modeling process, laying preparation for future automated AI-driven aviation solutions.

### Master Project: Automated SES Pruning Tool

The System Entity structure (SES) is an important high-level ontological framework in the discipline of flight simulation eventualities. It meticulously identifies a widget's components, relationships, and structural additives, improving the clarity and consistency of modeling and simulation. This paper presents a way to automatically prune SES. Automated SES pruning enhances automated scenario generation, facilitating efficient and precise criteria-driven scenario generation.

### Publication: Critical Scenario Techniques for Automated Vehicles: Literature Review

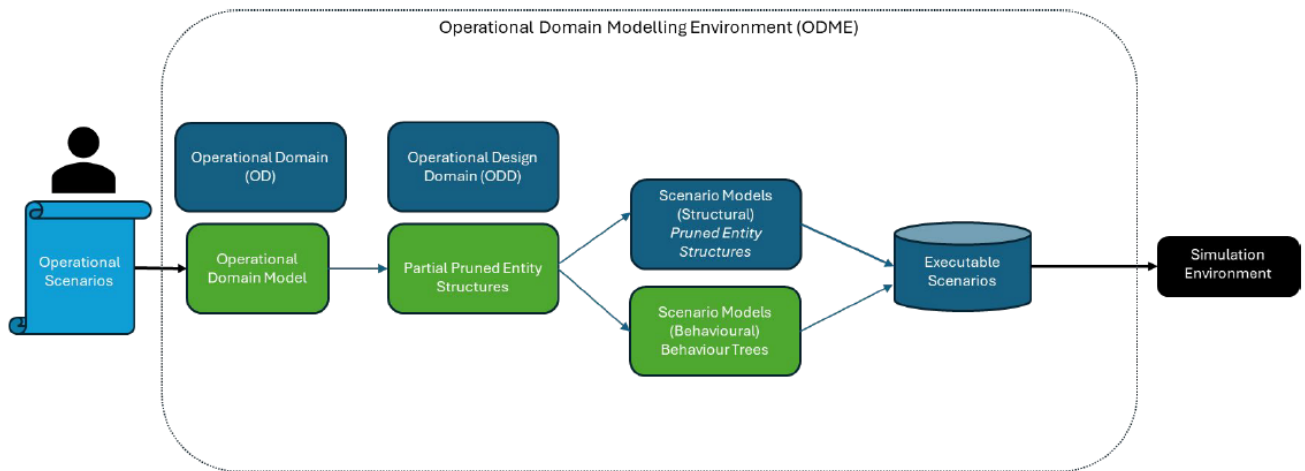
As Automated Driving Systems (ADS) become more widely used, there is rising worry regarding their safety and security. Traditional verification techniques, such as evaluating the vehicle's performance over a certain number of miles or kilometres, are insufficient to assess ADS risk. Instead, alternate approaches, such as scenario-based testing, which involves assessing the vehicle's performance in simulated situations that match real-world settings, are required to determine the system's safety and performance. This article presents a literature review on the importance of critical scenario analysis in ensuring the safety and reliability of ADS. Critical scenario analysis is a complete approach for identifying, quantifying, prioritising, selecting, and validating the most critical situations for ADS development and testing. ADS can reduce the frequency of accidents and fatalities caused by human error. Through this literature review, readers will understand the importance and benefits of critical scenario analysis methods and approaches, allowing them to systematically evaluate risks and opportunities and better comprehend the potential outcomes of future scenarios.

## Startup' Publication: A Lean Approach to the Control of Long Distance Unmanned Aerial Vehicles Using DTMF Signals on GSM

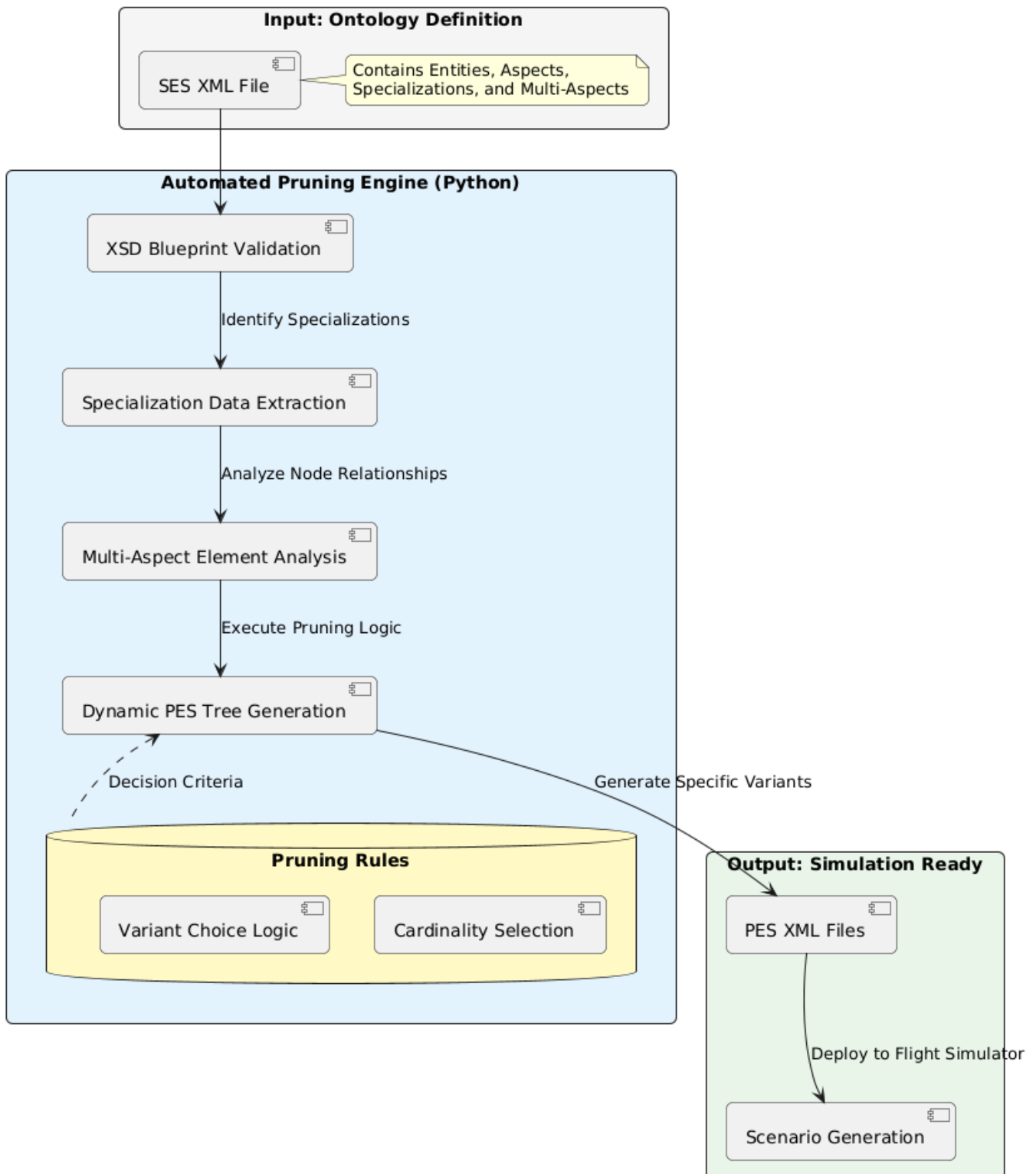
It is a study to solve the problem of long distance control which is the most basic problem of civilian and military unmanned aerial vehicles currently used. Here, by making the GSM communication system suitable for controlling unmanned aerial vehicles by the DTMF method, a lean alternative for distance problematic and expensive systems is presented.

## 7. Visual Portfolio & Diagrams

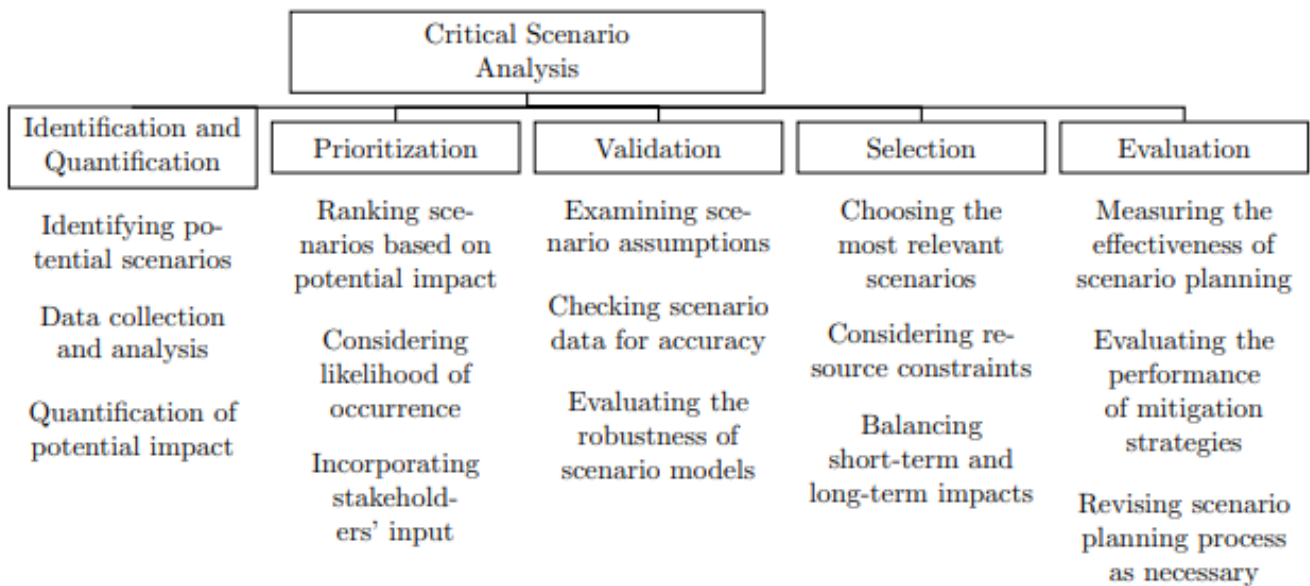
### Thesis & Research Diagrams



## Automated SES Pruning Workflow Architecture

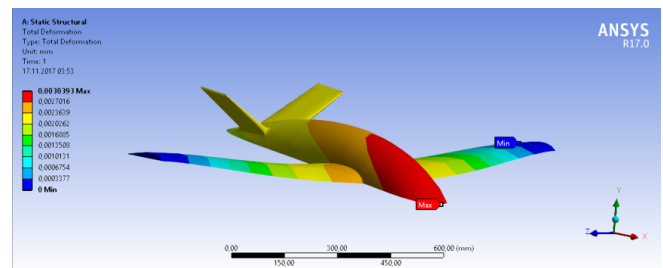
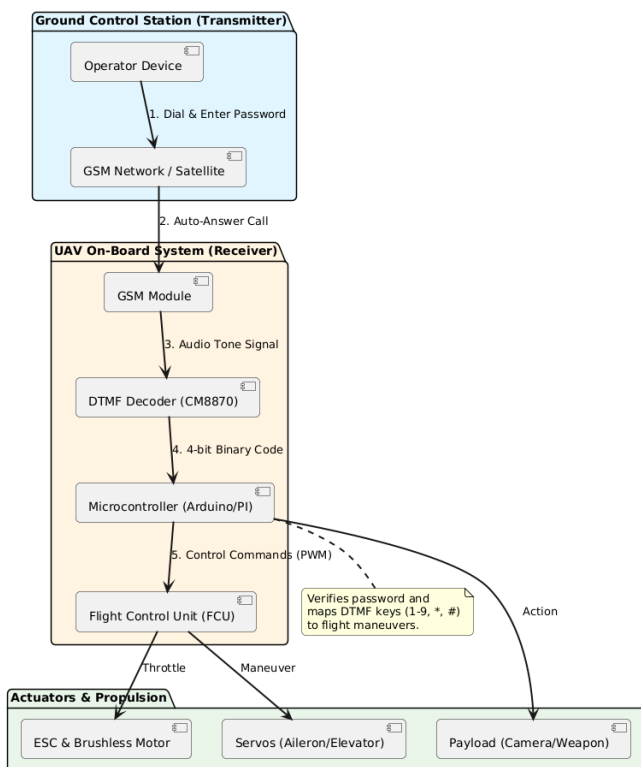


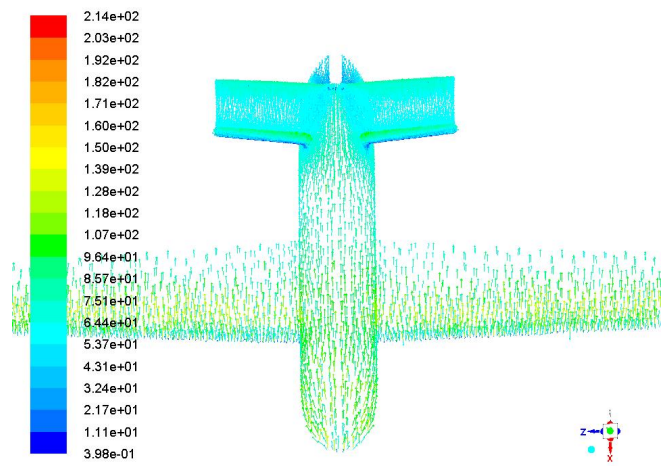
Developed by Kaan Akgün - TU Clausthal



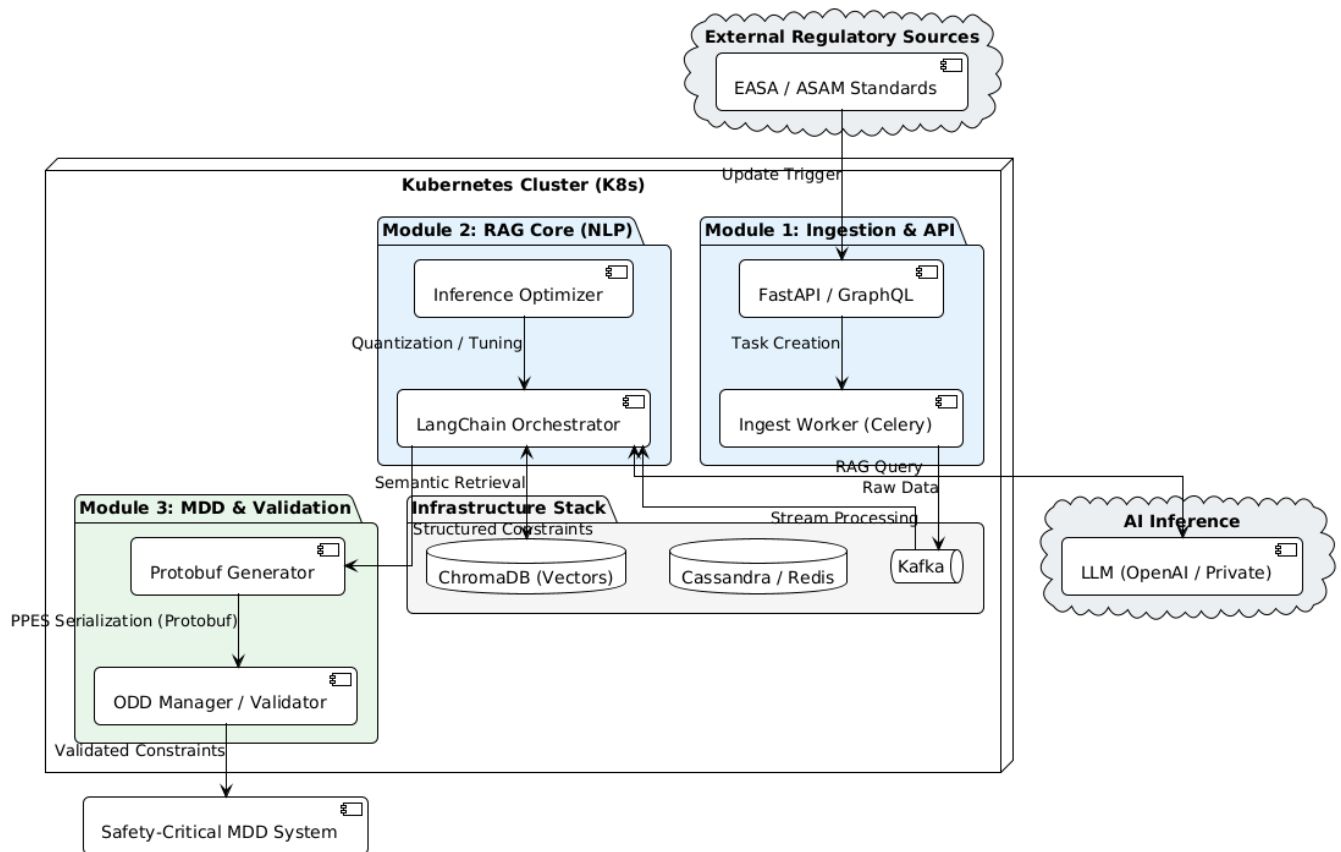
## Startup Prototypes (UAV GSM Control)

GSM-DTMF Based Long Distance UAV Control Architecture

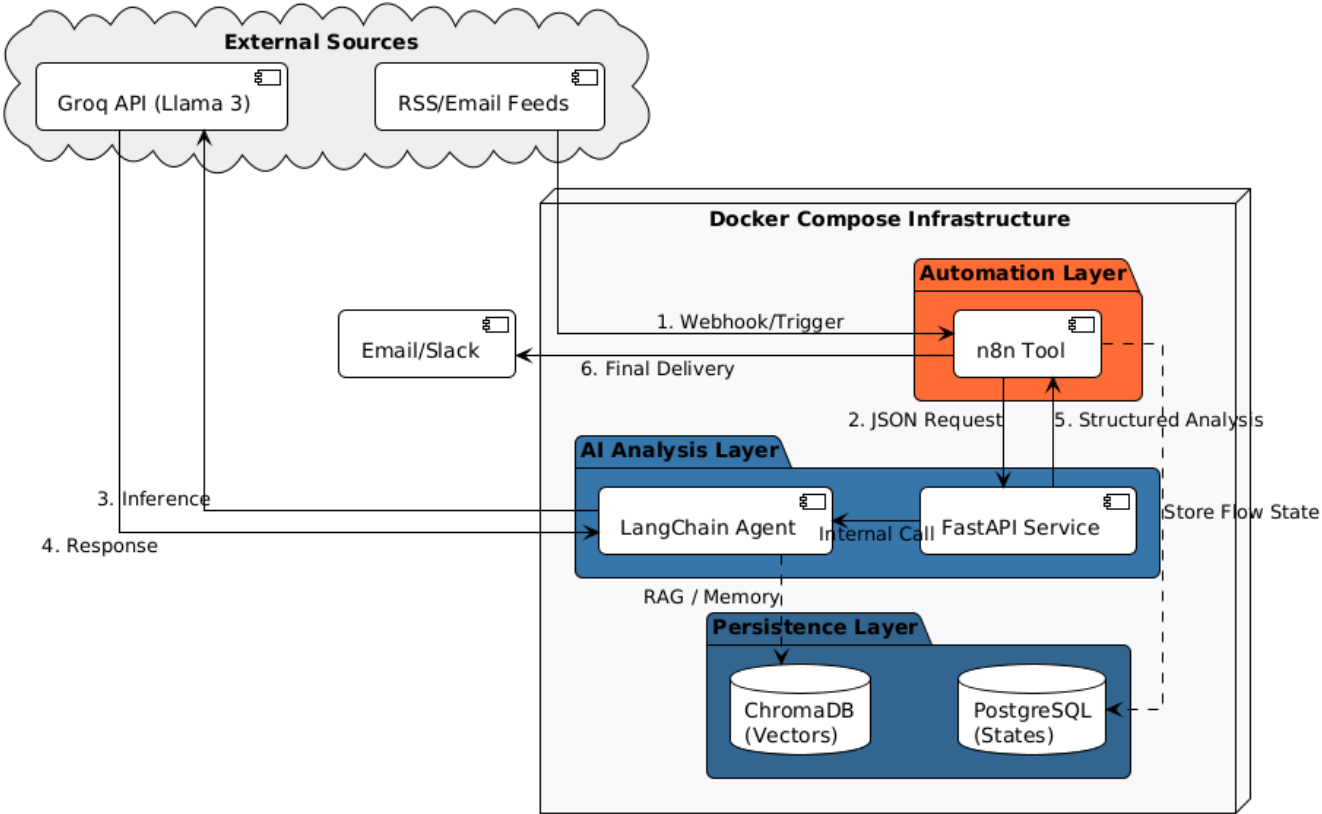




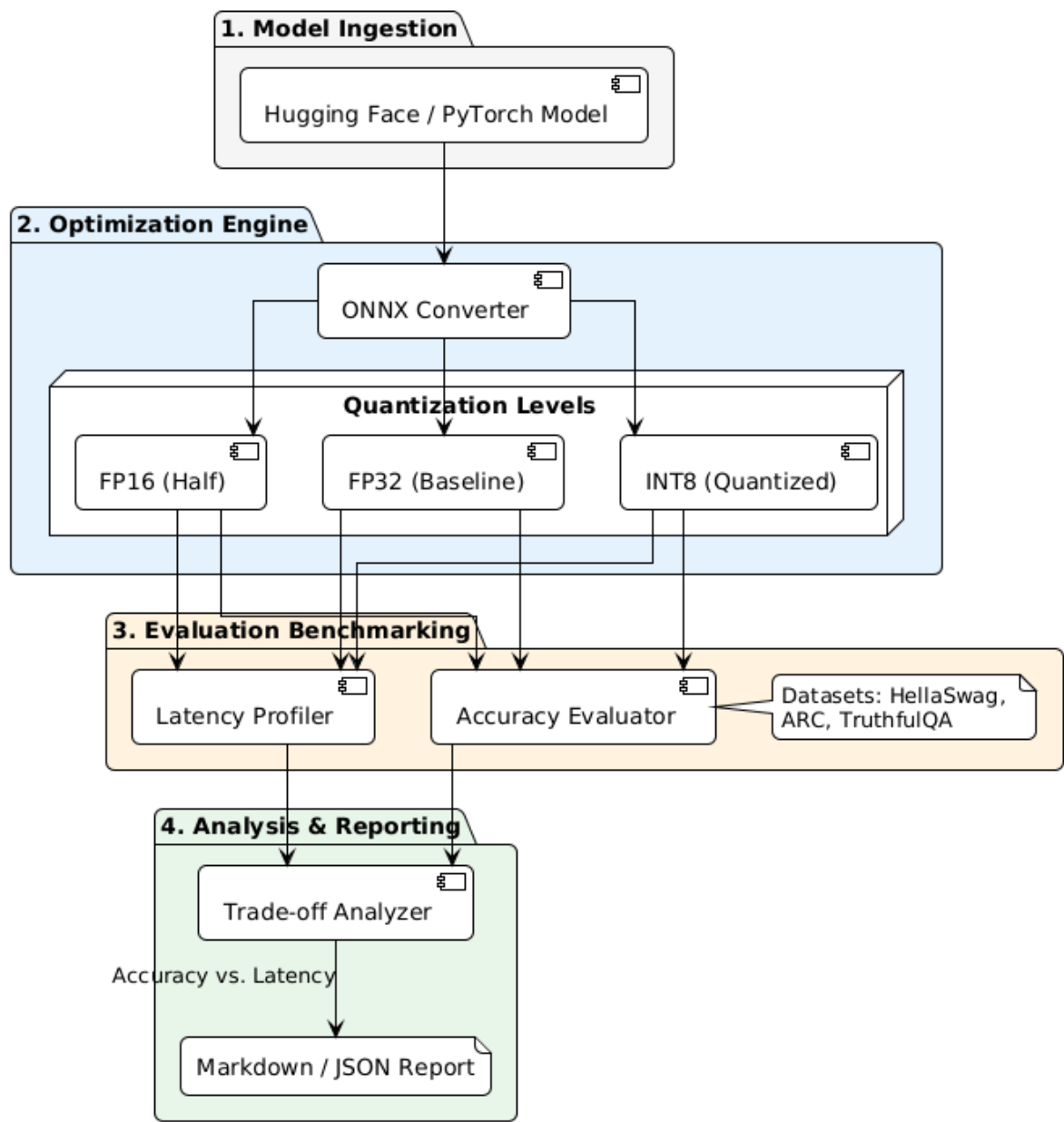
## Autonomous Safety Constraint Validation (ASCV-GenAI) - Architecture



# AI Research Pipeline - Orchestrated Docker Architecture

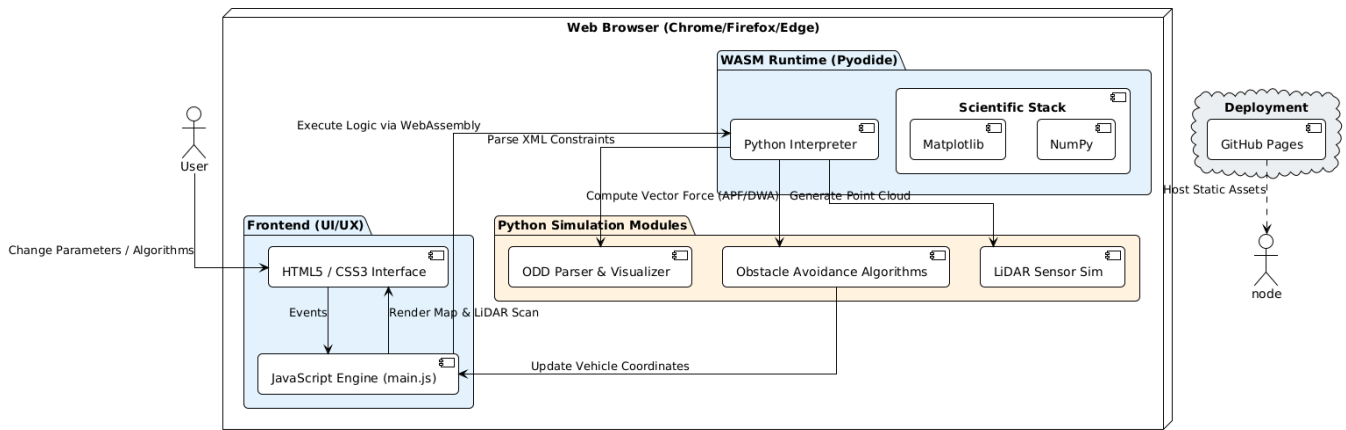


# LLM Inference Optimization & Accuracy Trade-off Analyzer

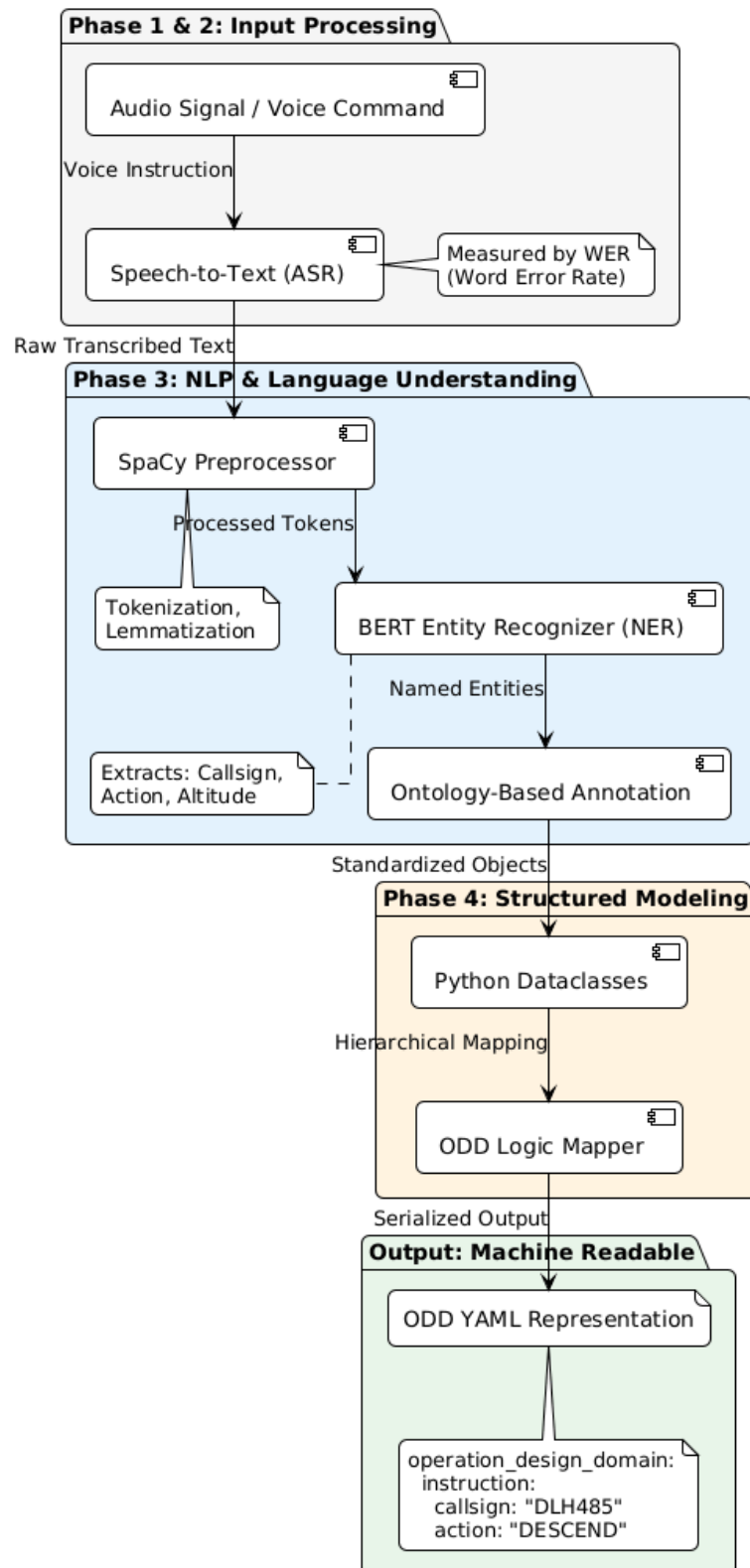


Optimization	Logic
FP32	No loss, high latency
FP16	Minimal loss, 2x faster
INT8	Possible loss, 4x faster

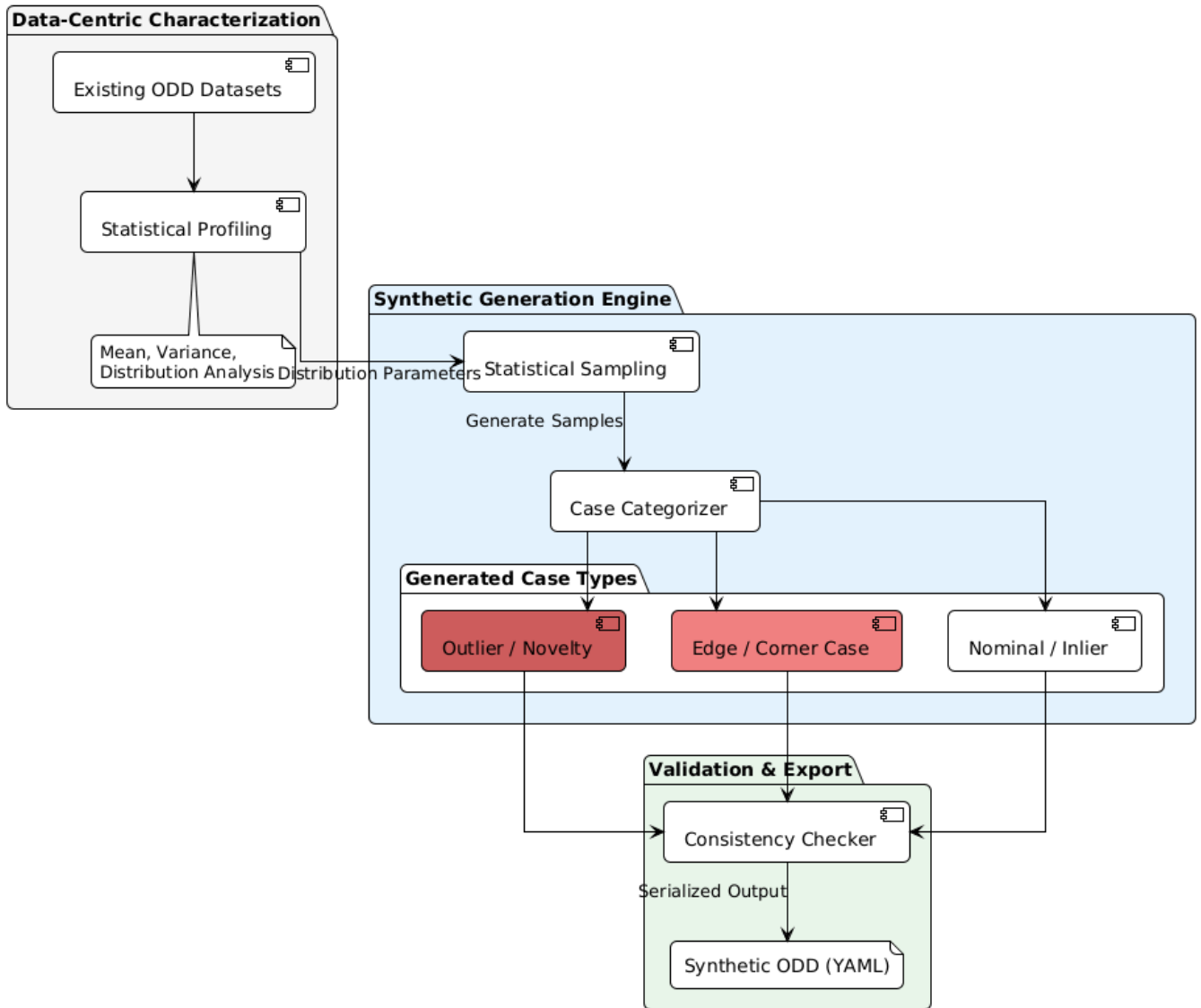
## autoVal-SLAM: Browser-Based Simulation Architecture



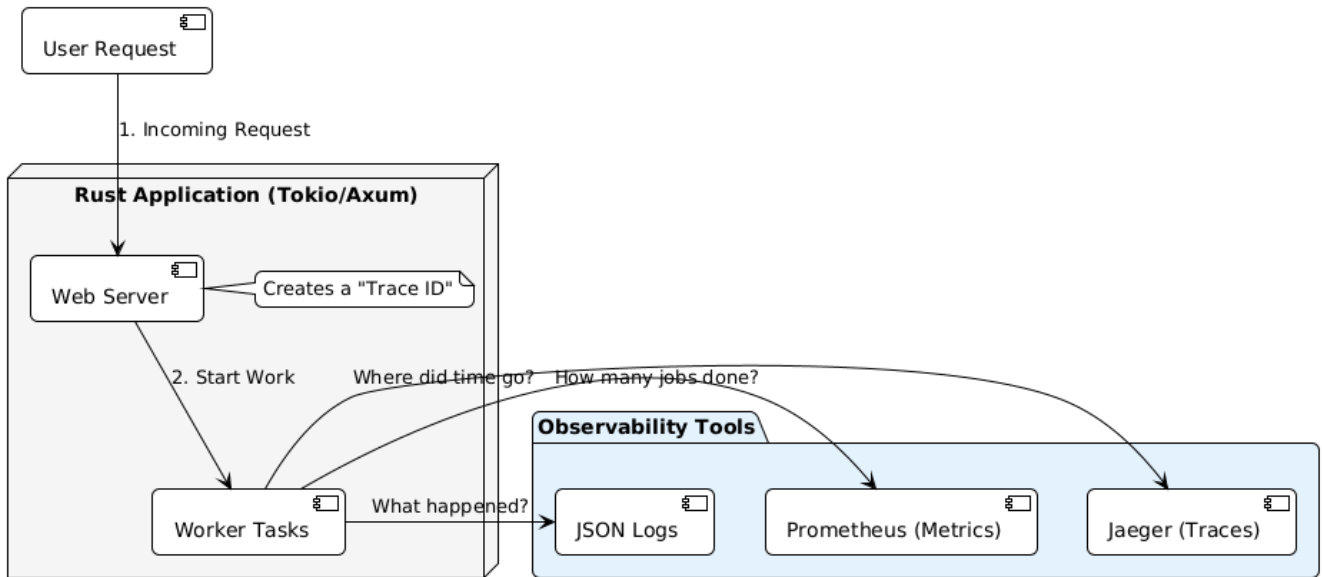
# Natural Language to ODD YAML Converter - Workflow Architecture



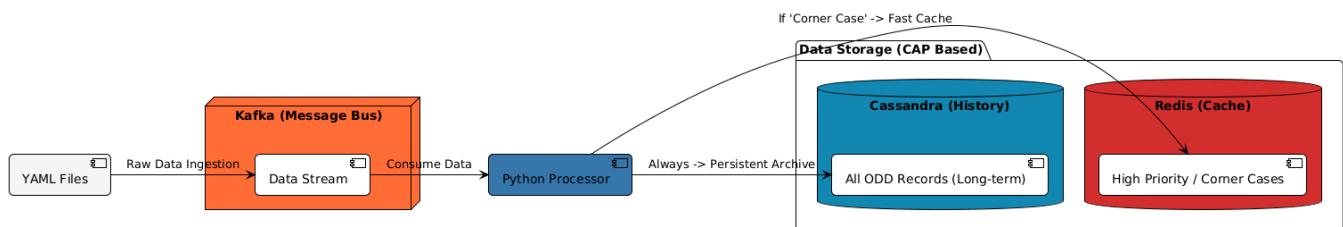
# Synthetic ODD Data Generation Pipeline



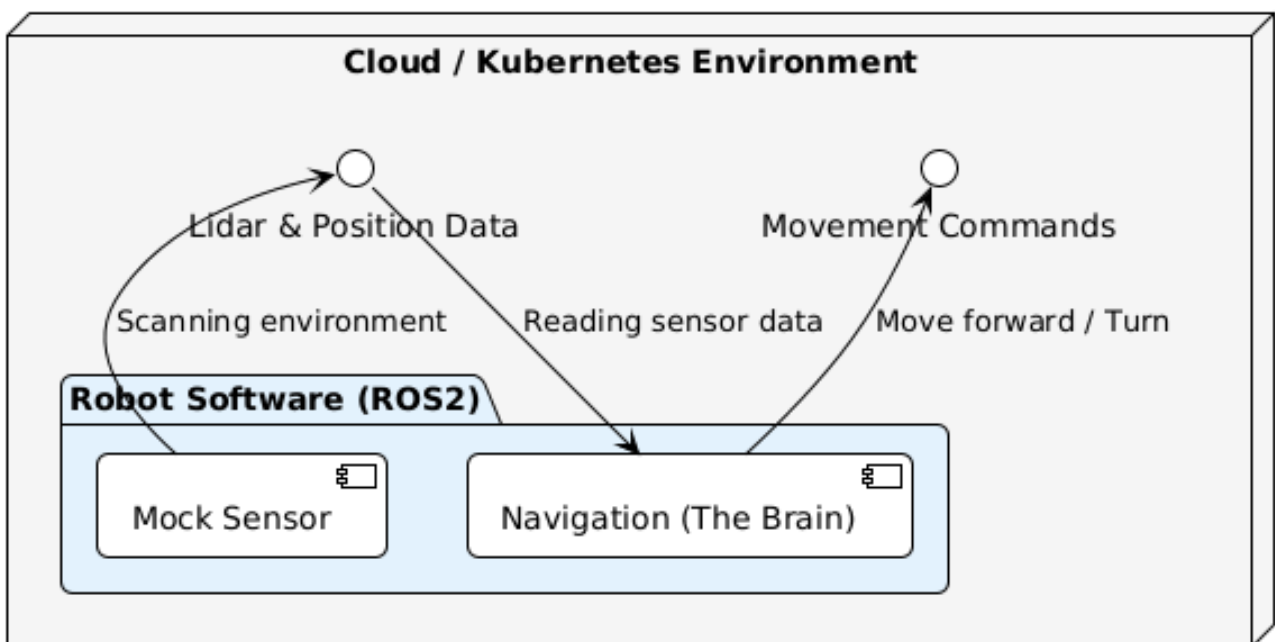
## Observability Gateway



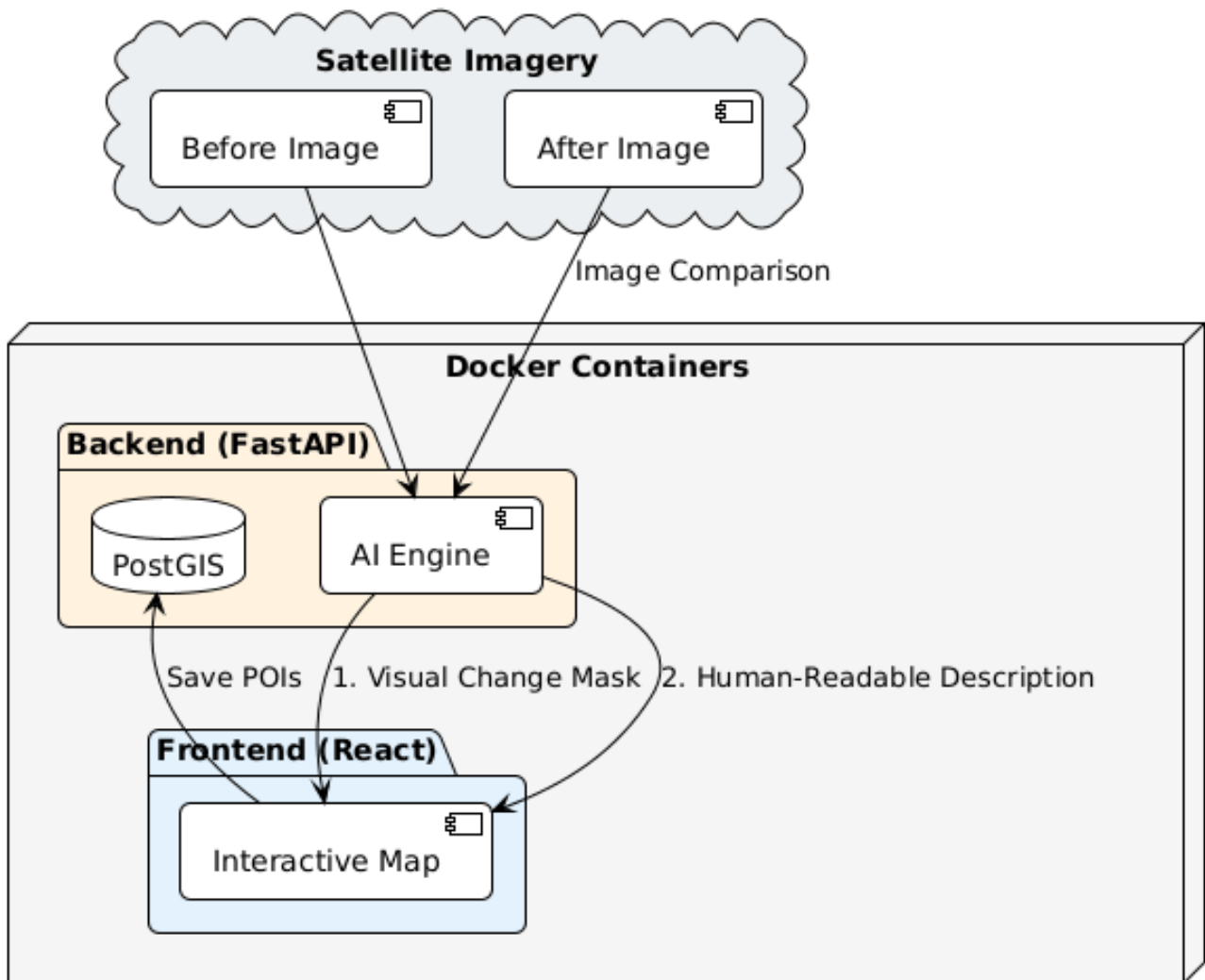
## ODD Processing Pipeline (CAP Theorem PoC)



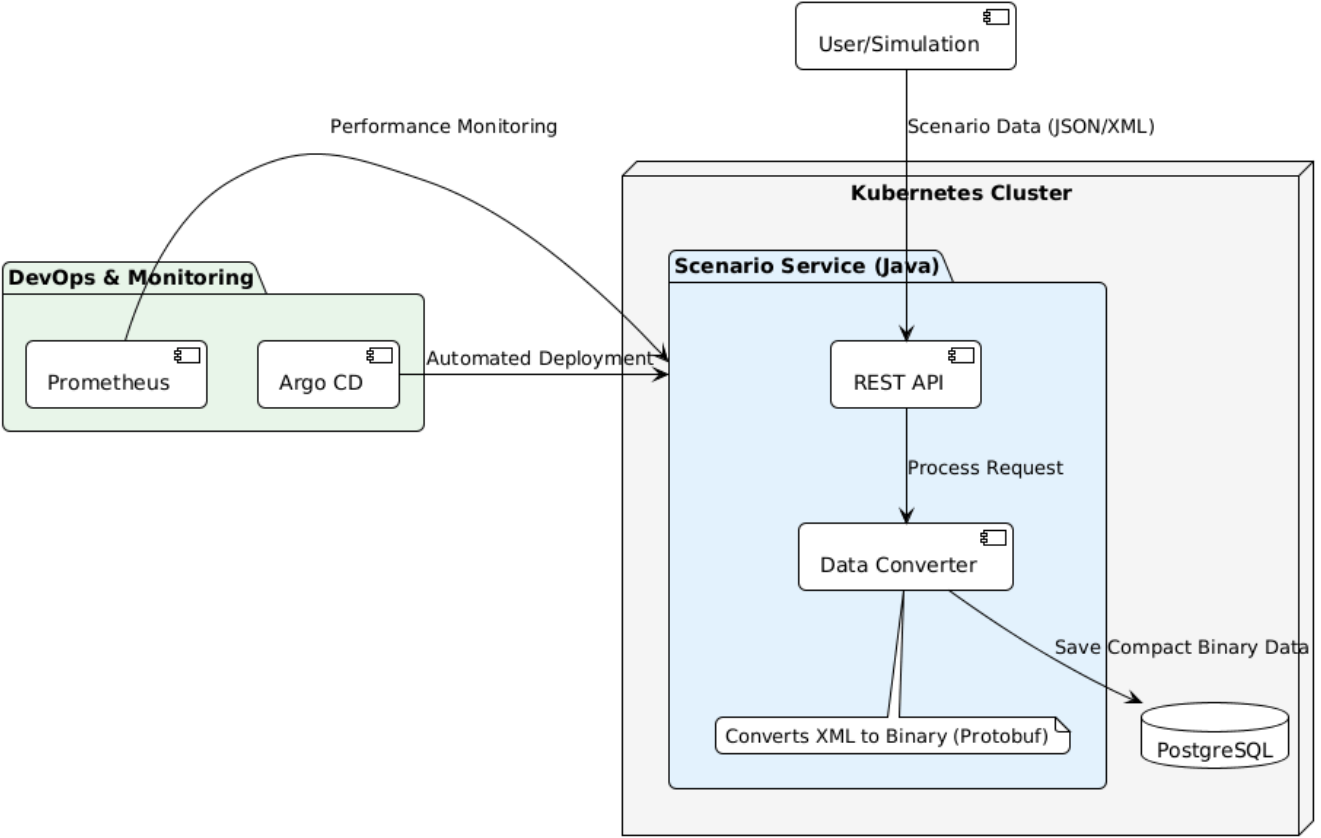
## Smart Factory Robot (Simple Flow)



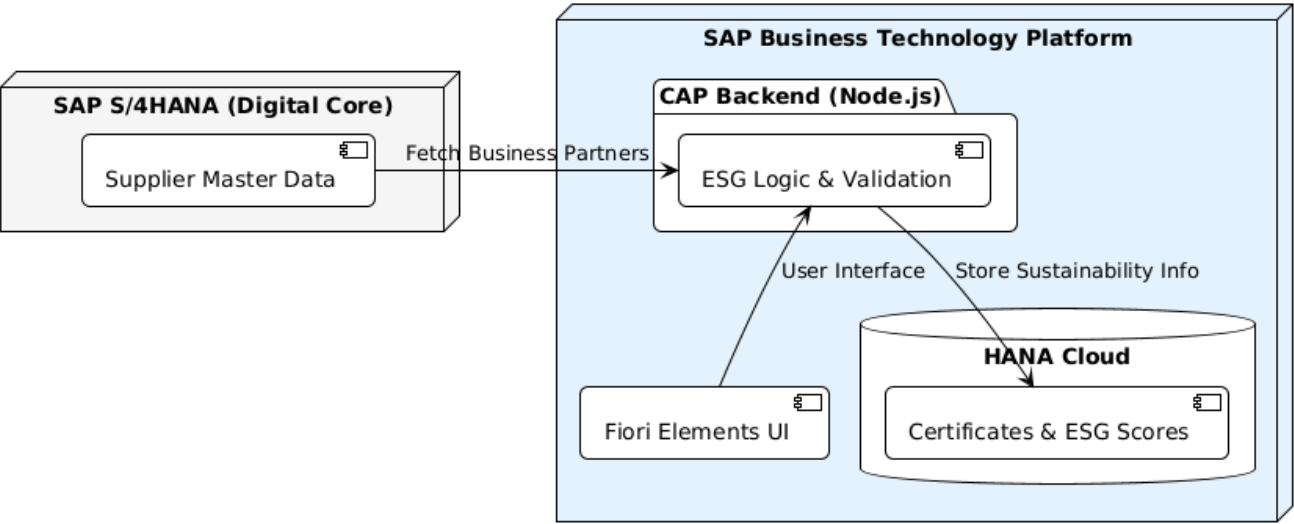
# PulseView: AI Change Detection



ScenarioForge: High-Efficiency Data Storage



GreenChain: SAP BTP Sustainability Extension



# PulseView: AI Change Detection

