WP2 Deliverable

Deliverable D2.2

This document presents the ENGINUITY Deliverable D2.2. It defines the industrial needs and framework requirements derived from the use cases elicited and documented in WP2 Deliverable D2.1. The identified use cases represent the key industrial challenges that the ENGINUITY project aims to address.

The ENGINUITY framework is described as a software framework structured into three interconnected layers: the Tool Layer, the Model Layer and the AI Layer. These layers are aligned with the framework capabilities identified through the analysis of industrial needs and use cases. Based on these capabilities, a set of framework requirements is derived to ensure that the ENGINUITY framework can effectively support the targeted industrial applications and use cases.

Industrial Needs

The collected industrial needs are a motivation for the ENGINUITY use cases.

ID	Need Name	Need Description
N-01	Requirements quality	Engineers need high quality requirements in early stages of development, so that unwanted variation of implementation is avoided.
N-02	Domain implementation	During domain implementation, engineers expect that the framework supports domain implementations according to ORU/OTA concepts, so that domain implementations remain correct and online updates can be executed reliably.
N-03	Flexible OTA concept	Engineers expect applicable extensions to ORU/OTA concept, so that future changes can be integrated.
N-04	Change traceability	Engineers expect that changes/adjustments are documented and traced, so that evidence for fulfilling legal obligations can be provided.
N-05	Automated format migration	During diagnostic authoring, the technical author requires automatic migration of heterogenous diagnostic inputs or non-standardized artefact into standardized ODX/OTX or to compatible domain specific languages, so that the workflow remains continuous and manual migration errors are avoided.
N-06	AI-assisted validation	During AI-assisted artefact generation, diagnostic authors require the integration of validation into the authoring workflow, so that errors can be discovered in the development environment.
N-07	AI-assisted traceability	During the AI-assisted authoring workflow, diagnostic authors require full traceability coverage of transformation decisions, so that error chains can be detected.
N-08	Human in the loop review	During diagnostic authoring, diagnostic authors require to review, edit and approve AI-generated proposals at individual step level before final artefact generation, so that individual output parts can be adjusted without reworking the complete result.

ID	Need Name	Need Description
N-09	Data protection & sovereignty	The tool shall ensure data-sovereign operation within the corporate network, preventing confidential diagnostic data from leaving the controlled company environment.
N-10	Prompt-driven artefact generation	During diagnostic authoring, engineers require that validated test sequences and/or diagnostic data models are created without the need to author data manually, so that engineers who are not familiar with diagnostic standards are able to create complex diagnostic artefacts.
N-11	Early impact estimation	Engineers require concepts to enable early impact assessment of system changes, so that decisions regarding change effects can be made.
N-12	Estimation of sustainability KPI values	During the (vehicle) conception phase, engineers require life cycle assessment values so that system properties can be optimized with respect to sustainability objectives.
N-13	Automated knowledge integration	During engineering activities, engineers expect that the framework automatically integrates and provides access to information from heterogeneous engineering artefacts and repositories, so that time-consuming information collection is reduced.
N-14	Standards based data exchange	During collaboration activities, engineers require standards for data exchange, so information can be exchanged seamlessly across heterogeneous tool environments.
N-15	Reuse enablement	During development activities, suppliers expect that the framework automatically provides visibility of reusable development artefacts and their applicability based on received information, so that the effort required to identify reuse opportunities is minimized.
N-16	Multi objective optimization	During system design activities, engineers need to evaluate design alternatives against competing objectives such as performance, cost and environmental impact, so that balanced design solutions can be selected.
N-17	Model roundtrip collaboration	During collaborative development activities, engineers expect that models and sub-models can be seamlessly exchanged, integrated and synchronized across organizational boundaries, so that consistency is maintained and model roundtrip efforts between involved stakeholders are minimized.
N-18	Early Detection of Schedule and Cost Risks	During project execution and monitoring activities, project controls lead needs to identify schedule slippages and cost deviations as early as possible, so that corrective actions can be initiated before project performance is significantly impacted.
N-19	Compliance-Aware Work Planning	During construction and site execution activities, engineering managers require continuous verification of utility crossing permissions and design sign offs, so that work is only started when all compliance requirements are fulfilled.
N-20	Proactive Quality and Safety Management	Engineering managers need to detect emerging quality and safety issues before they develop into recurring defects or incidents, so that preventive measures can be implemented in a timely manner.
N-21	Efficient Access to Operational Information	During daily operational and coordination activities, PMO staff require rapid access to project information from multiple data sources, so that informed decisions can be made without manual data consolidation efforts.

ID	Need Name	Need Description
N-22	Reliable Inspection Data Handover	During operation activities, operations engineers need complete, traceable and easily accessible quality and inspection records, so that operational teams can rely on validated information without repeating inspections activities.
N-23	Compliance Documentation	During system design activities, engineers need evidence to which degree the system under development already complies with given rules or regulations.

Capabilities

To bridge the gap between industrial needs and framework requirements, an intermediate capability engineering step was introduced. Initially, framework capabilities were identified for each use case to address the respective industrial needs. In a second step, the identified capabilities were consolidated across all use cases by removing overlaps, harmonizing terminology and merging related capabilities. An overview of the resulting consolidated framework capabilities is provided in Table 1. These capabilities serve as the basis for deriving the framework requirements presented in the subsequent sections.

Table 1: Framework Capability Overview

Capability	**Sub Capabilities**
Knowledge Management & Semantic Integration	Information Retrieval
	Knowledge Extraction
	Knowledge Graph Management
	Knowledge Integration
	Semantic Linking
Artefact Generation	SysML v2 Management
	Diagram Generation
	Code Generation
	Artefact Transformation
Model-Based Enablement	Model Information Management
	Model Governance
	Reusability
	Architecture Recommendation
	Variant Modelling
Human Governance & Sovereign Operation	Human-In-The-Loop Operation
	Autonomous Operation Control
Quality Assurance	Consistency Verification
	Compliance Verification
	Traceability Assurance
	Validation Support
	Auditability
Decision Support	Decision Traceability
	Explainable Reasoning
	Dependency Analysis
Change Management Support	Change Simulation
	Change Impact Assessment
	Constraint Identification
	Workflow Orchestration
Design Space Exploration	Simulation Composition
	Trade-Off Studies
	Pareto Optimization
	Life Cycle Assessment
	Simulation-based Root-Cause Analysis

Knowledge Management and Semantic Integration

Knowledge Management & Semantic Integration enables the systematic extraction, integration, organization and interconnection of engineering data from heterogeneous sources and formats. The capability establishes a unified semantic knowledge foundation that combines information from engineering artefacts, rules, knowledge repositories and AI systems. By making knowledge machine-interpretable and semantically connected, it improves traceability, knowledge discovery, reasoning and the efficient reuse of information across disciplines, organizations and lifecycle phases.

Information Retrieval

Information Retrieval enables the understanding of engineering context and the identification and retrieval of relevant information from heterogeneous data sources. The capability provides context-specific knowledge required for a given engineering task and forms the foundation for AI-assisted analysis, reasoning and decision-making. By delivering the most relevant information in a structured and traceable manner, it enables users to efficiently generate accurate, explainable and actionable outcomes.

Knowledge Extraction

Knowledge Extraction identifies, captures and structures relevant knowledge from heterogeneous engineering artefacts and data sources. The capability enables the transformation of information from documents, models, code, rules and natural language into machine-interpretable knowledge to support integration, reasoning and reuse.

Knowledge Integration

Knowledge Integration ensures the establishment of a unified knowledge base across multiple engineering formats. The capability enables the management and semantic integration of knowledge originating from heterogeneous artefacts, abstraction layers, data sources, models, rule sets and knowledge repositories with varying availability levels, including domain, non-domain, public, in-house, certification and customer-specific knowledge.

Semantic Linking

Semantic Linking establishes intelligent relationships between structured and unstructured engineering information based on contextual meaning rather than explicit references alone. The capability enables the connection of requirements, design artefacts, model elements, documents, decisions and domain knowledge to create a unified knowledge network. By applying semantic analysis and AI-driven reasoning, it uncovers hidden dependencies and contextual relationships that may not be formally modelled within a system or product. This enhances traceability, knowledge discovery and navigation across complex engineering environments. Semantic Linking improves the accessibility of relevant information and supports more informed engineering decisions including support of impact analysis. As a result, users can efficiently identify related content, understand underlying rationales and gain deeper insights into system dependencies.

Knowledge Graph Management

Knowledge Graph Management establishes and maintains a structured semantic representation of engineering knowledge. The capability enables the management of entities, relationships, ontologies and metadata to enable knowledge connectivity, traceability, reasoning and efficient retrieval across heterogeneous sources.

Artefact Generation

Artefact Generation enables the automated creation, management, visualization, conversion and integration of engineering artefacts across the system lifecycle. The capability supports the automatic generation of formal engineering artefacts, including SysML v2 models, diagnostic functions, test artefacts, rules and executable code from requirements, specifications and engineering knowledge.

SysML v2 Management

SysML v2 Management enables the creation, reading, modification and maintenance of SysML v2 model artefacts throughout the engineering lifecycle. Following a Systems-as-Code approach, the capability supports the automated generation, interpretation and processing of SysML v2 textual models derived from requirements, specifications, engineering artefacts and domain knowledge. It ensures consistent model structures, facilitates model reuse and collaboration and provides a foundation for downstream activities such as visualization, analysis, transformation and model-based engineering workflows.

Diagram Generation

Diagram Generation automatically transforms SysML v2 code and model information into visual engineering representations. The capability supports the creation of consistent, up-to-date diagrams that improve model understanding, communication, navigation and review activities. It facilitates the interpretation of complex system architectures and model structures by presenting engineering information in an intuitive graphical form.

Code Generation

Code Generation automatically generates SysML v2 textual models and software code from requirements, specifications, engineering knowledge and model information. The capability enables the transformation of engineering intent into machine-processable and executable representations, reducing manual effort, improving consistency and accelerating engineering workflows.

Artefact Transformation

Artefact Transformation converts, harmonizes and integrates engineering artefacts across heterogeneous formats and representations. The capability enables the seamless exchange and transformation of information from documents, spreadsheets, code, models and domain-specific formats into consistent artefacts that support interoperability, automation and downstream engineering activities.

Model-Based Enablement

Model-Based Enablement establishes a consistent and resilient foundation for collaboration across engineering disciplines. The capability enables structured management, governance, reuse and analysis of model information while supporting the development and evaluation of system architectures and variants. By ensuring that model knowledge remains accessible, consistent, reusable and traceable across different abstraction levels and stakeholder views, it facilitates efficient model-based engineering throughout the lifecycle.

Model Information Management

Model Information Management enables the structured storage, organization, access and maintenance of model information throughout the engineering lifecycle. The capability supports the management of metadata, versions and configurations across heterogeneous models and engineering domains. It ensures that model information remains consistent, accessible, traceable and reusable for downstream engineering activities, collaboration and model-based decision-making.

Model Governance

Model Governance establishes and enforces policies (modelling guideline), standards, roles and processes for model development and usage. The capability ensures model quality, consistency, traceability, compliance and controlled collaboration throughout the engineering lifecycle.

Reusability

Reusability enables the systematic reuse of engineering artefacts, models, patterns and knowledge throughout the engineering lifecycle. The capability supports the management and provision of reusable model libraries and facilitates the efficient adaptation of existing engineering assets to new products/systems. It enables the integration and reuse of OEM-provided models and development artefacts within supplier-specific engineering environments, reducing duplication of effort while ensuring consistency, traceability and interoperability across organizational boundaries.

Architecture Recommendation

Architecture Recommendation supports the identification and evaluation of system architectures based on engineering requirements, constraints, objectives as well as existing design knowledge. The capability enables the assistance of engineers in exploring architectural alternatives and assessing them against criteria such as performance, cost, complexity, sustainability, compliance, maintainability and reuse potential. By leveraging existing models, patterns and engineering knowledge, it enables informed architecture decisions and accelerates the development of optimized system designs.

Variant Modelling

Variant Modelling enables the definition, management and analysis of system/ product variants within model-based engineering environments. This capability enables the capturing of commonalities and variabilities across product families, platforms, configurations as well as customer-specific solutions, ensuring consistency and traceability throughout the engineering lifecycle. It supports the systematic derivation, evaluation and maintenance of variant-specific model artefacts while reducing duplication of effort and improving reuse. By representing variability directly within engineering models, the capability facilitates efficient configuration management, impact analysis as well as collaboration across stakeholders and organizations. The capability can be realized using model-based variability mechanisms and native variant management approaches provided by SysML v2.

Human Governance & Sovereign Operation

Human Governance & Sovereign Operation ensures that AI-assisted engineering activities remain controllable. The activities are aligned with human responsibility. The capability enables the combination of human oversight with controlled autonomous operation to enable trustworthy collaboration between engineers and AI agents while protecting company know-how and customer information.

Human-In-The-Loop Operation

Human-In-The-Loop Operation ensures that engineers remain involved in the supervision, validation and approval of AI-assisted engineering activities. The capability enables mechanisms for human review, decision checkpoints and intervention in automated workflows, ensuring accountability, engineering responsibility as well as trustworthiness. It enables experts to validate generated artefacts, control access to company know-how and customer information. In addition, it enables experts to maintain sovereign decision-making throughout the engineering lifecycle.

Autonomous Operation Control

Autonomous Operation Control enables the controlled and sovereign operation of AI-driven engineering functions within predefined boundaries and policies. The capability enables the definition of which activities may be executed autonomously, under which conditions human intervention is required and how access to proprietary knowledge, engineering artefacts and customer information is governed. It ensures that autonomous actions remain transparent, controllable and aligned with organizational responsibilities, compliance requirements, as well as engineering objectives.

Quality Assurance

Quality Assurance ensures consistency, completeness, correctness and compliance of engineering artefacts throughout the engineering lifecycle. This capability supports the detection of inconsistencies, ambiguities, missing information as well as quality deficiencies while enabling the verification and validation of engineering outcomes. By providing traceability, auditability and systematic quality assessments, it increases confidence in engineering results and supports predictable, reliable and high-quality engineering processes.

Consistency Verification

Consistency Verification identifies and evaluates inconsistencies across requirements, models, architectures, artefacts and engineering data. The capability ensures alignment between engineering representations and supports the early detection of conflicts and contradictions throughout the lifecycle. In case of requirements, it includes checks for duplicates, inconsistencies, incomplete or missing elements.

Compliance Verification

Compliance Verification assesses engineering artefacts against standards, regulations, contractual requirements and internal engineering guidelines. The capability supports automated compliance checks and increases confidence in regulatory and organizational conformity.

Traceability Assurance

Traceability Assurance establishes and maintains traceability links across requirements, models, engineering artefacts, decisions, tests and implementation elements. The capability enables transparency, impact analysis and compliance activities.

Validation Support

Validation Support assists engineers in evaluating whether engineering solutions satisfy stakeholder needs, system requirements, standards and intended operational objectives. The capability supports validation through model analyses, simulations, reviews and test-related artefacts.

Auditability

Auditability ensures that engineering artefacts, decisions, model changes and AI-assisted activities can be transparently reviewed and reconstructed. The capability supports the provisioning of evidence of engineering rationale, compliance and lifecycle activities for audits and assessments.

Decision Support

Decision Support enables informed and transparent engineering decisions throughout the system lifecycle. The capability helps engineers understand dependencies, evaluate alternatives and assess the rationale behind recommendations and analysis results. By providing traceable decisions, explainable outcomes and evidence-based insights, it increases confidence in engineering activities and supports consistent, reproducible and well-founded decision-making.

Decision Traceability

Decision Traceability captures, documents and maintains decision rationales, assumptions, alternatives and outcomes throughout the engineering lifecycle. The capability ensures that decisions remain transparent, explainable and reproducible over time.

Explainable Reasoning

Explainable Reasoning provides transparent explanations for recommendations, analyses and AI-generated outputs. The capability enables engineers to understand the underlying rationale, assumptions, supporting evidence and decision logic behind results. It supports evidence-based decision-making through references to relevant artefacts (e.g. models, requirements) and knowledge sources, allowing users to evaluate the validity and credibility of generated outcomes. Furthermore, the capability provides intuitive result visualizations and ensures that analyses and recommendations are predictable, reproducible and traceable across engineering activities.

Dependency Analysis

Dependency Analysis identifies and evaluates relationships and dependencies between requirements, models, components, functions, architectures and engineering artefacts. The capability supports impact assessment, risk mitigation and informed engineering decisions.

Change Management Support

Change Management Support enables systematic assessment and management of engineering changes across interconnected artefacts, models and system elements. The capability helps engineers understand how proposed modifications propagate through complex engineering environments. Affected elements are identified, so that potential impacts can be evaluated before implementation. By providing insights into change dependencies and their consequences, it supports informed decision-making to reduce risks.

Change Simulation

Change Simulation evaluates proposed engineering modifications by simulating their effects on requirements, architecture, tests etc. before implementation. The capability helps with the analysis of the propagation of changes through interconnected engineering elements and assesses their impact on requirement fulfilment, system behaviour and lifecycle objectives. By leveraging model-based analyses and knowledge-driven dependency information, it supports risk reduction and evidence-based change decisions.

Change Impact Assessment

Change Impact Assessment enables the systematic evaluation of how modifications to requirements, functions, components or system elements affect the overall system/product architecture. By leveraging traceability relationships and dependency analysis based on knowledge representations, the capability supports the identification of both direct and indirect impacts across multiple levels of system/product abstraction levels. It supports top-down and bottom-up analysis to provide a comprehensive understanding of change propagation, "potentially impacted items" and "confirmed impacted items" throughout the system. The capability combines structural model information with contextual knowledge to improve assessment accuracy and completeness. Automated prioritization and visualization of affected elements help engineers focus on critical areas and make informed decisions. This reduces analysis effort, minimizes the risk of overlooking dependencies and improves change management efficiency.

Constraint Identification

Constraint Identification identifies and analyses technical, architectural, regulatory, organizational and lifecycle-related constraints for a change or optimization request that influence engineering change decisions and limit feasible solution alternatives. The capability enables the automation of the uncovering of dependencies, assumptions and restrictions across multiple models and engineering artefacts. The capability supports feasible and compliant system evolution beyond technical specifications, including economic, environmental and safety considerations.

Workflow Orchestration

Workflow Orchestration coordinates and automates engineering activities, simulations, analyses and tool interactions across engineering change processes. The capability supports the management of dependencies between tasks, data flows and engineering artefacts throughout the change lifecycle while enabling repeatable and scalable workflows. It supports the execution of integrated engineering change processes involving simulations, life cycle assessments, knowledge-based activities, thereby improving efficiency, consistency and automation.

Design Space Exploration

Design Space Exploration enables systematic exploration and evaluation of alternative engineering solutions within a defined design space. The capability supports engineers in understanding the effects of design decisions, balancing competing objectives and identifying optimal solutions under given constraints. By combining simulation-based analyses, optimization methods and evidence-based assessments, it provides a transparent foundation for informed engineering decisions and the development of efficient, robust and sustainable systems.

Simulation Composition

Simulation Composition enables the specification, integration and orchestration of simulation models across disciplines, domains and abstraction levels. The capability supports the definition of simulation goals, the configuration of multi-physics and multidisciplinary simulations as well as the management of interfaces between simulation models. By composing interoperable simulation environments, it enables comprehensive system analyses. Moreover, it supports design exploration activities.

Trade-Off Studies

Trade-Off Studies support the exploration and evaluation of alternative system architectures, designs and engineering solutions against predefined criteria such as performance, cost, complexity, sustainability and risk. By making competing priorities and their consequences transparent, the capability helps engineers and stakeholders understand the trade-offs between different options and identify solutions that best satisfy project-specific goals. The resulting evaluations provide a traceable and evidence-based foundation for architecture and design decisions.

Pareto Optimization

Pareto Optimization identifies solution alternatives that provide the best balance between competing objectives within a design space (multi-objective optimization). The capability supports the evaluation of large sets of candidate solutions against defined goals and constraints and determines Pareto-optimal alternatives where no objective can be improved without degrading another. It supports the estimation and analysis of Pareto fronts, enabling engineers to understand trade-offs between conflicting objectives and select solutions that best satisfy project-specific priorities.

Life Cycle Assessment

Life Cycle Assessment evaluates the environmental performance of systems and products throughout their entire life cycle. The capability supports sustainability-driven engineering decisions by assessing ecological impacts, resource consumption, emissions and environmental KPIs based on reliable lifecycle data and suitable assessment methods. It includes predictive life cycle inventory modelling to estimate future lifecycle impacts of products with long lifespans, enabling environmental considerations to be integrated into early design and optimization decisions.

Simulation-based Root-Cause Analysis

Simulation-based Root Cause Analysis identifies the underlying causes of engineering issues, deviations, failures and undesired system behaviour through the systematic analysis of simulation results. The capability enables the exploration of cause-effect relationships within the design space by analysing dependencies between design parameters, requirements and simulation artefacts. By leveraging simulation data, engineering knowledge and connected system information, it supports the identification of performance drivers and design limitations, thereby enabling informed design decisions, optimization as well as the development of improved solution alternatives.

Framework Requirements

The identified capabilities support the derivation of framework requirements which are listed in the table below.

ID	Requirement Name	Requirement Description	Acceptance Criteria	Constraints
FR-01	Multi-agent system	The framework shall provide a multi-agent system capable of orchestrating specialized AI agents to support and execute the functionalities required by the project use cases.	Specialized agents can be configured and executed individually or as part of multi-agent workflows. Agents can exchange information and results through standardized interfaces. At least one complete workflow involving multiple interacting agents can be demonstrated for each project use case. Agent outputs are traceable and can be reviewed by a human user.	Protected deployment scenarios and confidential engineering data
FR-02	Modular and extensible multi-agent system	The framework shall provide a modular and extensible multi-agent architecture that enables the integration, replacement, configuration and orchestration of specialized agents and models.	New agents can be added without modifying the core framework architecture. - Existing agents can be reused and combined into different workflows. -Agent configurations can be adapted to project-specific requirements. - At least two use cases reuse a common framework capability or agent	n.a.
FR-03	LLM Abstraction Layer	The framework shall be compatible with a variety of LLMs.	Framework is compatible with leading / industrial standard AI models.	n.a.

ID	Requirement Name	Requirement Description	Acceptance Criteria	Constraints
FR-04	Knowledge Base Integration	The framework shall provide a curated, versioned knowledge base of diagnostic standards.	AI-Agents have sufficient knowledge of diagnostic standards.	n.a.
FR-05	Sustainable AI	The framework shall be designed, developed, deployed and operated in a manner that minimizes environmental impact through efficient use of computational energy and infrastructure resources while meeting all defined functional and performance requirements.	The AI system records and reports energy consumption during operation.	Sustainability measures shall not degrade mandatory functional capabilities.
FR-06	Human-centered Assessment Workflow	The framework shall support collaborative interaction between automated analysis capabilities and engineering experts through review and approval mechanisms.	The framework allows designated engineering experts to review analysis results before approval.	-
FR-07	Secure and Sovereign Engineering Data Processing	The framework shall ensure secure handling of proprietary engineering information and support deployment in restricted industrial environments.	All engineering data processed by the framework remain within the designated deployment environment during operation.	-
FR-08	Decision Visualization	The framework shall provide visualization capabilities that present analysis results, decision alternatives and supporting evidence to understand and assess decision recommendations.	The framework displays the data sources, rationale or evidence used to generate a decision recommendation. Users can compare at least two decision alternatives using the provided visualization capabilities.	-
FR-09	Multi-format artefact integration	The framework shall support ingestion and processing of heterogeneous engineering artefacts.	Artefacts from multiple formats can be imported and transformed into a common representation.	n.a.
FR-10	Data governance	The framework shall provide mechanisms for governing engineering		

ID	Requirement Name	Requirement Description	Acceptance Criteria	Constraints
		data, models and knowledge assets, including ownership, versioning, lifecycle management and access policies.		
FR-11	Data Protection	The framework shall ensure that required engineering data, models, knowledge assets and services are available to authorized users and agents when executing workflows.		
FR-12	Data Accessibility	The framework shall provide controlled and efficient access to engineering information for both human users and AI agents.	Authorized users and agents can search, retrieve and consume relevant artefacts from connected repositories. Access permissions are consistently enforced.	

Outlook: Use Case Demonstrators

Based on demonstrators, tests are described to support the validation of use cases and the use case/framework requirements. The results are described in deliverable 2.4. In the following, an outlook of the current demonstrators should be given. In addition, the capabilities for the ENGINUITY framework are allocated to demonstrators representing which capabilities are realized by which demonstrator. The demonstrators will be provided in deliverable D2.3.

Every use case provider has identified a demonstrator. The ENGINUITY demonstrators include:

- Diagnostic Demonstrator – Harvester Scenario
- Electric motor with imbalance
- Device Management Platform and demonstrator car
- Vehicle Motion Control model

Diagnostic Demonstrator – Harvester Scenario: This demonstrator showcases a complete diagnostics workflow in a controlled and interactive environment. It enables users to visualize and guide vehicle diagnostics, including trouble code analysis, fault identification, measurement evaluation, guided service procedures and ECU flashing. The demonstrator combines authoring capabilities for ATL flows, data models and user interfaces with a runtime environment that executes diagnostic workflows and communicates with the vehicle. ECU simulation allows realistic testing and validation without requiring a physical machine. As a result, the platform makes complex real-world diagnostics engineering challenges visible, executable and researchable, supporting the development and evaluation of innovative service solutions.

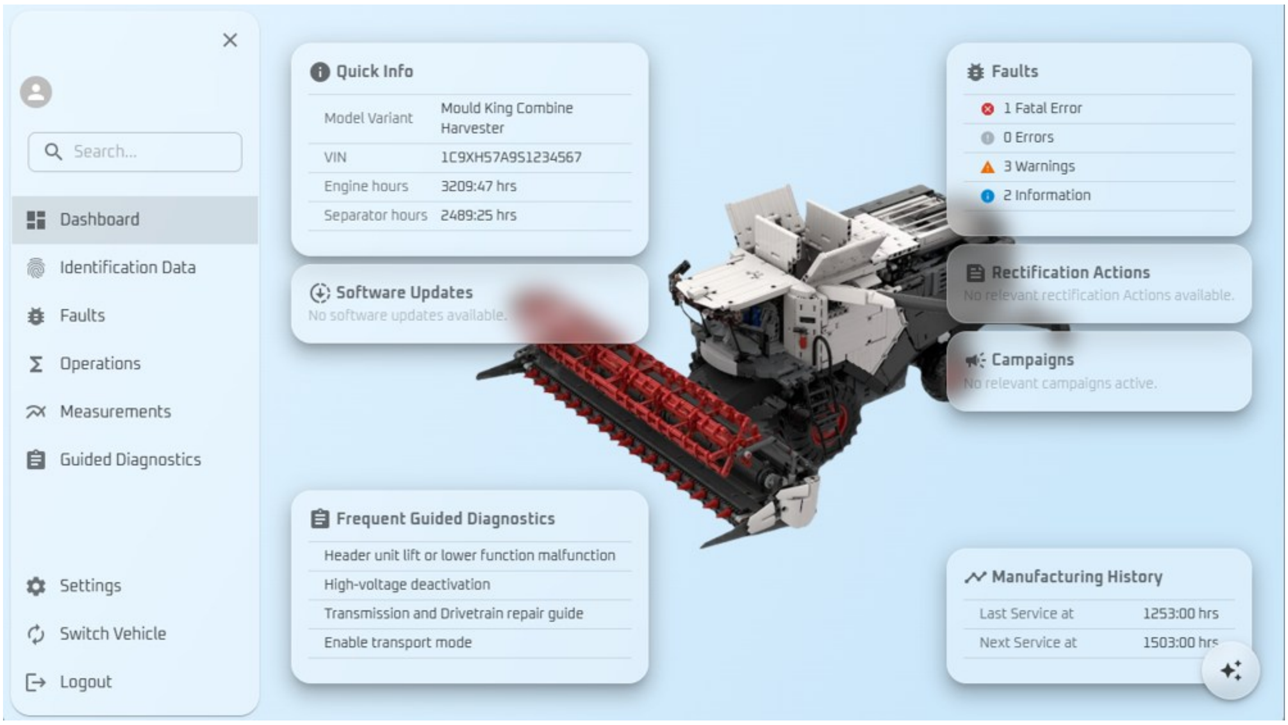

Figure 1: Exemplary User Interface of Diagnostic Demonstrator – Harvester Scenario

Electric motor with imbalance: The electric motor with Imbalance demonstrator showcases end-to-end data continuity from engineering to manufacturing, enabling a consistent digital thread across the system life cycle. It supports life cycle assessment (LCA), impact analysis and simulation-based design exploration by connecting engineering, manufacturing and sustainability-related data. LCA calculations can incorporate both internal system data and environmental impact values provided by suppliers of electric motor components, resulting in more accurate sustainability assessments. Variants within a product line are considered to support the selection of appropriate reference configurations and facilitate sustainability comparisons. The demonstrator also enables the bundling and exchange of simulation and LCA artefacts through a Digital Data Package (DDP) and supports the integration of Digital Product Passport (DPP) information. Furthermore, changes in motor imbalance can be detected and analysed using simulation-based root cause identification, helping to understand the impact of design and manufacturing decisions on product behaviour.

Figure 2: Electric motor with imbalance demonstrator

Device Management Platform and demonstrator car: The demonstrator showcases a flexible platform for evaluating and validating modern software-defined system architectures and connected services. It provides an environment for rapid prototyping, testing and deployment of software applications across distributed hardware and software components. The platform supports key use cases such as remote software updates, device management and lifecycle management of connected systems. By integrating simulation, virtualization and deployment capabilities, the demonstrator enables the assessment of architecture concepts and operational workflows in a realistic setting. Its modular and reusable design facilitates experimentation with new technologies while reducing integration effort. The demonstrator serves as a practical environment for exploring future software-centric engineering and operation approaches.

Vehicle Motion Control Model: ZF uses, as an example for its application scenarios in ENGINUITY, a fictitious collaborative development project between an automotive manufacturer and ZF as Tier-1 supplier. In this example, ZF develops an extended Vehicle Motion Control system (VMC+) that adds autonomous trajectory following to the conventional VMC functions of steering, braking, acceleration and suspension/damping.

The VMC+ demonstrator is used to evaluate framework capabilities across multiple system levels, organizational units and engineering domains throughout the product lifecycle, from request for quotation (RFQ) through integration, verification and validation (IVV). Reusability of artefacts, models and methodologies is another key objective of the demonstrator.