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UNIVERSITY OF APPLIED SCIENCES

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Department of Electrical Engineering and Information Technology

From Static Profiles to Semantic Libraries

The Evolution of Modeling Guidelines and Consistency Validation in SysML v2

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1 Expose

The development of modern Cyber-Physical Systems (CPS) is characterized by immense complexity, a challenge managed by Model-Based Systems Engineering (MBSE). [1–3] This approach relies on standardized frameworks like Systems Modeling Language (SysML) to model discipline-specific subsystems in a central model. [1, 3–9] However, the flexibility of SysML leads to inconsistencies, non-reusable models, making modeling guidelines essential for ensuring quality, consistency, and reusability in MBSE practices. [1, 4–6]
The introduction of SysML v2 is intended to enhance MBSE adoption over its predecessor. [7] SysML v2's new features - particularly its textual syntax , formal metamodel, and standardized API - aim at improving precision, expressiveness, usability, interoperability, and extensibility. [1, 4, 5, 7, 8]

This paper investigates the following question: *How does the introduction of SysML v2 fundamentally change the landscape of modeling guidelines in MBSE, particularly regarding their formalization, validation, and enforcement?*

- **Hypothesis 1 (Opportunity - Formalization):** SysML's formal metamodel and textual notation enable a new class of precise, verifiable guidelines that were not possible in SysML v1. [3]
- **Hypothesis 2 (Opportunity - Validation):** The v2 metamodel allows for automated semantic and syntactic consistency checking, moving guidelines from passive documents to active, verifiable parts of the model. [5]
- **Hypothesis 3 (Challenge - Complexity):** The language design of SysML v2 itself presents challenges to maintainability and portability, which complicates the development and adaptation of guideline sets. [8]

The methodology will be an exploratory literature review. The primary sources will be recent (2022-2025) academic papers from IEEE, INCOSE, and relevant journals that specifically address the implementation, validation, and methodology of SysML v2.

2 Outline Concept

Introduction The development of modern Cyber-Physical Systems (CPS) is characterized by immense complexity, a challenge managed by Model-Based Systems Engineering (MBSE). [1–3]
This approach relies on standardized frameworks like Systems Modeling Language (SysML) to model discipline-specific subsystems in a central model. [1, 3–9]
However, the abstract nature of SysML leads to inconsistencies, non-reusable models, making modeling guidelines essential for ensuring quality, consistency, and reusability in MBSE practices. [1, 4–6]
jansen, cibrian, boelsen, bergemann, molnar, zavada

Theoretical Background: From UML to KerML

Status Quo: Guidelines in SysML v1

The Paradigm Shift: Guidelines in SysML v2

Advanced Validation Capabilities in v2

Discussion: The Cost of Power

Conclusion

Bibliography

[1] BOELSEN, K. ; MAY, M. ; JACOBS, G. ; AL. et: SysML v2 based modelling guidelines for mechanical system elements. In: *Forsch Ingenieurwes* 89 (2025), No. 60. http://dx.doi.org/10.1007/s10010-025-00827-w. – DOI 10.1007/s10010–025–00827–w. – **[TOP 3]** This paper argues that SysML v2's abstract nature creates a high risk of inconsistent modeling. It proposes a new, formal set of guidelines using SysML v2's features. This source is a cornerstone as it provides a direct example of new formal guidelines and structures.

[2] BERGEMANN, Sebastian: Challenges in Multi-View Model Consistency Management for Systems Engineering. Version: 2022. http://dx.doi.org/10.18420/modellierung2022ws-009. In: *Modellierung 2022 Satellite Events*. Bonn : Gesellschaft für Informatik e.V., 2022. – DOI 10.18420/modellierung2022ws–009, p. 77–89. – This paper investigates the critical challenge of managing model consistency across multiple viewpoints in MBSE. It analyzes existing approaches against a set of industrial requirements, identifying gaps in current methods. This work is essential as it defines the problem of inconsistency that formalized SysML v2 guidelines are intended to solve.

[3] DEHN, Simon ; JACOBS, Georg ; HÖCK, Philipp ; HÖPFNER, Gregor: Enhancing model-based development with formalized requirements: integrating temporal logic and SysML v2 for comprehensive state and transition modeling. In: *Forschung im Ingenieurwesen* 89 (2025), No. 1, p. 53. – This paper presents a multi-step approach for formalizing requirements in SysML v2 using temporal logic. It provides a concrete example of new formal validation techniques and highlights challenges regarding scalability and complexity.

[4] LI, Zirui ; FAHEEM, Faizan ; HUSUNG, Stephan: Collaborative Model-Based Systems Engineering Using Dataspaces and SysML v2. In: *Systems* 12 (2024), No. 1. http://dx.doi.org/10.3390/systems12010018. – DOI 10.3390/systems12010018. – ISSN 2079–8954. – This paper explores how to enable collaborative MBSE by combining SysML v2 modeling with a secure framework for data exchange. The proposed solution relies on a modeling guideline to maintain consistency and interoperability, which is why its relevant as it justifies why standardized guidelines are essential for leveraging SysML v2's new features in a collaborative, multi-tool environment.

[5] CIBRIÁN, Eduardo ; OLIVERT-ISERTE, Jose ; DÍEZ-FENOY, Carlos ; MENDIETA, Roy ; LLORENS, Juan ; RODRÍGUEZ, José M.: Ensuring Semantic Consistency in SysML v2 Models Through Metamodel-Driven Validation. In: *IEEE Access* 13 (2025), p. 121444–121457. http://dx.doi.org/10.1109/ACCESS.2025.3587786. – DOI 10.1109/ACCESS.2025.3587786. – **[TOP 3]** This paper advances SysML v2 model

validation by presenting an automated method for ensuring structural and semantic consistency, making this work directly relevant to the proposed hypotheses.

[6] YILDIRIM, Unal ; CAMPEAN, Felician ; KORSUNOVS, Aleksandr ; DOIKIN, Aleksandr: Flow heuristics for functional modelling in model-based systems engineering. In: *Proceedings of the Design Society* 3 (2023), p. 1895–1904. – This paper tackles the challenge of inconsistent functional modeling in MBSE by proposing flow heuristics to guide modelers. It highlights the issues my hypotheses address and demonstrates how structured guidelines can improve model quality, directly supporting the need for formalized SysML v2 guidelines.

[7] FRIEDENTHAL, Sanford: Future Directions for MBSE with SysML v2. In: *MODELSWARD*, 2023, p. 5–9. – This work outlines the vision for SysML v2, detailing its new features and how they are designed to overcome the limitations of SysML v1. This source provides authoritative support for all three hypotheses as it highlights the motivation behind SysML v2's development from the perspective of a primary developer.

[8] JANSEN, Nico ; PFEIFFER, Jerome ; RUMPE, Bernhard ; SCHMALZING, David ; WORTMANN, Andreas: The Language of SysML v2 under the Magnifying Glass. In: *J. Object Technol.* 21 (2022), No. 3, p. 3–1. – **[TOP 3]** This paper assesses SysML v2 language by evaluating its 2022-01 release against formal software language engineering guidelines. It provides a critical analysis of SysML v2's strengths and weaknesses, directly informing the hypotheses about its potential and challenges for formalized modeling guidelines.

[9] BEERS, Lasse ; NABIZADA, Hamied ; WEIGAND, Maximilian ; GEHLHOFF, Felix ; FAY, Alexander: A SysML Profile for the Standardized Description of Processes during System Development. In: *2024 IEEE International Systems Conference (SysCon)* IEEE, 2024, p. 1–8. – This paper addresses the challenge of standardizing process modeling in MBSE for non-experts by creating a lightweight SysML v1 profile based on the VDI/VDE 3682 standard, which uses OCL constraints for automated validation. It provides a case study of the SysML V1 era and sets the stage for exploring how SysML v2 can further enhance such guidelines.