Conference Paper Title*

*Note: Sub-titles are not captured in Xplore and should not be used

1st Nassim Awabdy
Fachbereich 5
Aachen University of Applied Sciences
Aachen, Germany
nassim.awabdy@alumni.fh-aachen.de

***Abstract*—This document is a model and instructions for LaTeX. This and the IEEEtran.cls file define the components of your paper [title, text, heads, etc.]. *CRITICAL: Do Not Use Symbols, Special Characters, Footnotes, or Math in Paper Title or Abstract.**

***Index Terms*—component, formatting, style, styling, insert**

I. Introduction

Modern Cyber-Physical Systems (CPS) are technical systems that combine mechanical, electronic, and software subsystems with physical elements embedded in the real world. The development of CPSs is becoming increasingly complex and challenging, due to their interdisciplinary nature and the need to ensure seamless integration between their physical and computational components [2], [3].

Model-Based Systems Engineering (MBSE) is a methodology for the development and management such complex systems, that addresses issues arising from the complexity and interdisciplinary nature of CPS, and provides the agility required to adapt to changing requirements and technologies. MBSE incorporates a centralized system model as the primary source of information, throughout the system lifecycle [2]–[6], [11].

SysML v1 has been widely adopted as the standard for modelling CPS and served as a key enabler MBSE. SysML v1 is a graphical, general purpose modelling language that is defined as an extension of the Unified Modeling Language (UML). Because it was built on top of UML, SysML v1 inherited several limitations from UML, that limited it's expressiveness and usability for CPS modelling. However, it still provided a solid foundation for specifying and analyzing a systems's behaviour, structure and requirements [3], [4], [7], [9], [11].

The release of SysML v2 represents the next generation of the Systems Modeling Language, designed as a comprehensive overhaul of SysML v1 that address it's limitations and enhance the efficacy of MBSE practices. However, despite the advancements introduced by SysML v2, many challenges remain in effectively utilizing the language for CPS modelling, particularly in ensuring model consistency, validation, and verification [3], [4], [11].

This shift creates a critical paradox: while SysML v2 offers higher precision through its formal axiomatic semantics, its abstract nature and flexibility can lead to inconsistent modeling practices if not strictly guided. Without standardized modeling guidelines, the reuse of system elements from model libraries becomes difficult, leading to redundant efforts and potential errors [3]. Consequently, the mechanism for implementing these guidelines must evolve from the profile-based constraints of SysML v1 to leverage the native formal capabilities of SysML v2.

Identify applicable funding agency here. If none, delete this.

II. Theoretical Background

A. MBSE

By emphasizing the use of **formal models** throughout the system lifecycle, MBSE supports the design, analysis, and verification of system representations, promoting consistency, traceability, and reusability across engineering processes. MBSE enables system architects to respond more quickly and effectively to numerous changes in requirements that occur during the development process.

In this context, the Models are crucial for specifying the high-level, architecture, functionality, uses cases, requirements, and constraints of the technical systems.

B. SysML v1 Foundations

C. SysML v2 Foundations

III. Results

A. SysML v1 Implementation of Modeling Guidelines

B. SysML v2 Implementation of Modeling Guidelines

C. Comparative Analysis

IV. Discussion and Implications

V. Conclusion and Outlook

Acknowledgment

References

[1] L. Beers, H. Nabizada, M. Weigand, F. Gehlhoff, and A. Fay, "A sysml profile for the standardized description of processes during system development," in 2024 IEEE International Systems Conference (SysCon). IEEE, 2024, pp. 1–8.

[2] S. Bergemann, "Challenges in multi-view model consistency management for systems engineering," in Modellierung 2022 Satellite Events. Bonn: Gesellschaft f¨ur Informatik e.V., 2022, pp. 77–89.

[3] K. Boelsen, M. May, G. Jacobs, and et al., "Sysml v2 based modelling guidelines for mechanical system elements," Forsch Ingenieurwes, vol. 89, no. 60, 2025.

[4] E. Cibrián, J. Olivert-Iserte, C. Díez-Fenoy, R. Mendieta, J. Llorens, and J. M. Álvarez Rodríguez, "Ensuring semantic consistency in sysml v2 models through metamodel-driven validation," IEEE Access, vol. 13, pp. 121 444–121 457, 2025.

[5] S. Dehn, G. Jacobs, P. Höck, and G. Höpfner, "Enhancing model-based development with formalized requirements: integrating temporal logic and sysml v2 for comprehensive state and transition modeling," Forschung im Ingenieurwesen, vol. 89, no. 1, p. 53, 2025.

[6] P. Dukić, "Generating sysmlv2 models from structured natural language," 2025.

[7] N. Jansen, J. Pfeiffer, B. Rumpe, D. Schmalzing, and A. Wortmann, "The language of sysml v2 under the magnifying glass." J. Object Technol., vol. 21, no. 3, pp. 3–1, 2022.

[8] H. Kausch, M. Pfeiffer, D. Raco, B. Rumpe, and A. Schweiger, "Model-driven development for functional correctness of avionics systems: a verification framework for sysml specifications," CEAS Aeronautical Journal, vol. 16, no. 1, pp. 33–48, 2025.

[9] V. Molnár, B. Graics, A. Vörös, S. Tonetta, L. Cristoforetti, G. Kimberly, P. Dyer, K. Giammarco, M. Koethe, J. Hester et al., "Towards the formal verification of sysml v2 models," in Proceedings of the ACM/IEEE 27th International Conference on Model Driven Engineering Languages and Systems, 2024, pp. 1086–1095.

[10] A. Ratzke, J. Koch, and C. Grimm, "Modeling and analysis of system models with constraints in sysml v2," in 2025 20th Annual System of Systems Engineering Conference (SoSE), 2025, pp. 1–6.

[11] S. Friedenthal, "Future directions for mbse with sysml v2." in MODELSWARD, 2023, pp. 5–9.

[12] S. Raedler, J. Mangler, and S. Rinderle-Ma, "Model-driven engineering method to support the formalization of machine learning using sysml," arXiv preprint arXiv:2307.04495, 2023.

[13] U. Yildirim, F. Campean, A. Korsunovs, and A. Doikin, "Flow heuristics for functional modelling in model-based systems engineering," Proceedings of the Design Society, vol. 3, pp. 1895–1904, 2023.

[14] Zavada, G. Kulcsár, V. Molnár, and Horváth, "Towards a configurable verification and validation framework for critical cyber-physical systems," in 2025 IEEE 8th International Conference on Industrial Cyber-Physical Systems (ICPS), 2025, pp. 1–6.

[15] Z. Li, F. Faheem, and S. Husung, "Collaborative model-based systems engineering using dataspaces and sysml v2," Systems, vol. 12, no. 1, 2024. [Online]. Available: https://www.mdpi.com/2079-8954/12/1/18