INCOSE

ASIA-OCEANIA SYSTEMS ENGINEERING CONFERENCE

Digital Twins for Brownfield Modernisation

Extending Legacy Systems with Safety-Critical Overlays

INCOSE AOSEC · 2025

AUTHORS
Deepaa Yoharani Ganesh

PUBLICATION DATE
July, 2026

SUBMISSION #
88

INCOSE PUBLICATIONS

Digital Twins for Brownfield Modernisation: Extending Legacy Systems with Safety-Critical Overlays

Deepa Yoharani Ganesh
Chair, INCOSE Systems and Software Working Group
deepaa.ganesh@incose.net

Abstract

Modernising brownfield systems is challenging due to entrenched Electronic Control Units (ECUs), constrained communication buses, and certification restrictions. Traditional high-fidelity digital twins, suited to greenfield platforms, are impractical in these contexts. This paper presents digital twin overlays—lightweight computational layers that repurpose existing subsystem signals to deliver actionable safety metrics without hardware redesign. The framework integrates three elements: signal reuse, lightweight computation, and dual-mode Human–Machine Interfaces (HMI). Verification follows a staged workflow: Software-in-the-Loop (SIL) ensures correctness, Hardware-in-the-Loop (HIL) validates integration, and Human-in-the-Loop (HITL) confirms usability. An automotive case study illustrates feasibility, with geometry parameters updated in real time under 200 ms latency and drivers achieving more than 95% correct navigation decisions. Results demonstrate overlays as a practical, certifiable pathway for incremental digital transformation of legacy platforms. While validated in automotive systems, the framework also generalises to aerospace, defence, and rail, offering a scalable path to enhancing safety and usability within certification constraints.

Keywords

Digital Twin Overlays, Brownfield Systems, Systems Engineering, Human–Machine Interface (HMI), Model- Based Engineering (MBE), Model Based Systems Engineering (MBSE), Software-in-the-Loop (SIL), Hardware- in-the-Loop (HIL), Human-in-the-Loop (HITL), Electronic Control Unit (ECU), Controller Area Network (CAN), Advanced Driver Assistance Systems (ADAS), Safety-Critical Systems.

Introduction

The Digital transformation is reshaping complex engineered systems. Digital twins: dynamic, data-driven models of system state and behaviour are central to this shift (Grieves, M, (2019)and INCOSE. (2023). Vision 2035). By linking subsystem signals with computational models and operational logic, they provide insights that support design, verification, and operation. While the literature often highlights digital twins in greenfield developments such as electric vehicles and autonomous platforms, the challenge of modernisation is more pressing in brownfield contexts.

In brownfield systems, redesign is rarely feasible. Electronic Control Units (ECUs) is tightly integrated and certified; communication buses such as the Controller Area Network (CAN) operate at fixed bandwidth; and architectures are locked in by years of development (ISO/IEC/IEEE. (2015). 15288). Industries such as automotive, aerospace, rail, and defence must continue operating platforms across decades, long after their original architectures were finalised. The result is a tension: safety, usability, and situational awareness must improve, but the traditional pathways of digital transformation, adding sensors, replacing ECUs, redesigning buses are impractical.

The central question addressed in this paper is therefore: How can digital transformation be achieved in brownfield systems without requiring new hardware or disrupting certification?

The proposed answer is the concept of digital twin overlays. These overlays do not attempt to replicate a high-fidelity lifecycle twin. Instead, they reuse legacy subsystem signals, apply lightweight computations, and present actionable safety information to operators. Overlays are therefore not replacements for system architecture but layers on top of it, bridging the gap between entrenched platforms and modern user needs.

This paper makes three main contributions:

1. A framework for brownfield overlays based on signal reuse, computational layering, and progressive verification.
2. A technical implementation in the automotive domain, including subsystem modelling, geometry computation, and Human Machine Interface (HMI) design.
3. A staged verification campaign (SIL→ HIL→ HITL) demonstrating correctness, feasibility, and operator comprehension.

Paper Structure. The remainder of this paper is organised as follows. Section 2 reviews the state of the art in digital twins for greenfield and brownfield systems. Section 3 introduces the proposed overlay framework. Section 4 presents the Vehicle Geometry case study, including implementation details and validation results. Section 5 discusses lessons learned and broader implications across safety-critical domains. Finally, Section 6 concludes with contributions, limitations, and directions for future research.

Greenfield Systems	Brownfield Twin
• New architectures	• Legacy architectures
• Integrated sensors	• Existing subsystem signal
• High-bandwidth networks	• Fixed communication buses
• Flexible ECUs	• Certification constraints
• Designed from outset	• Incremental overlays

Greenfield systems are designed with flexible architectures and rich sensing, enabling high-fidelity lifecycle twins. Brownfield platforms are constrained by fixed ECUs, buses, and certification; overlays layer new computation on existing signals to deliver safety value without hardware redesign.

State of Art

The concept of the digital twin has evolved from its origins as a design-time construct into a broader paradigm for system operation and lifecycle management (Grieves, M, 2019), (INCOSE. (2023)). In greenfield projects, twins are typically realised as high-fidelity models tightly coupled with rich sensing and high-bandwidth communications. Applications include electric powertrains, advanced driver assistance systems (ADAS), and autonomous vehicles, where sensor fusion enables detailed predictive analytics and continuous optimization (MathWorks. (2022)).

Brownfield systems, however, present a very different set of constraints. Defence platforms in service, aircraft certified under legacy regulations, and long-life automotive platforms cannot easily accommodate new sensors, ECUs, or communication architectures. For these systems, a digital twin must work with what already exists (Madni, A., & Sievers, M. (2021, ISO/IEC/IEEE. (2015). 15288). This requires a shift away from high-fidelity lifecycle twins toward overlay approaches that repurpose available signals.

Industrial practice anticipated this transition. For example, a Vehicle Geometry overlay, patented under (UK IP, 2015) and later released to production in 2018 demonstrated that actionable safety insights could be derived entirely from existing subsystem signals, without additional sensors, (Ganesh, D.Y, (2022)).

Recent Systems Engineering research has also highlighted this need. The (INCOSE. (2023) and ISO/IEC/IEEE. (2015). 15288) both emphasize incremental modernisation, traceability, and progressive verification across the lifecycle. Similarly, the (INCOSE. (2024)) points to model-based systems engineering (MBSE) as a foundation for digital transformation, even in constrained environments. Yet relatively little published work demonstrates how Model Based Systems Engineering (MBSE), model-based design toolchains (e.g., MATLAB/Simulink (MathWorks. (2022)), and staged verification workflows can be integrated into a cohesive assurance pathway for brownfield platforms.

Key insights from the literature are threefold:

1. Most published work addresses greenfield digital twins, while brownfield overlays remain underexplored.
2. Industrial practice demonstrated feasibility of overlays before widespread academic recognition (Ganesh.D. Y (2022)).
3. There is a gap in published methods that link MBSE, lifecycle standards, and progressive SIL– HIL–HITL verification into a coherent framework for brownfield modernisation (ISO/IEC/IEEE. (2015). 15288 and INCOSE. (2024)).

This paper addresses these gaps through a detailed case study of a Vehicle Geometry overlay, illustrating how digital overlays can extend the safety and usability of brownfield automotive platforms, and offering lessons applicable across aerospace, defence, and rail.

Framework for Brownfield Overlays

Extending brownfield platforms requires a framework that balances three concerns: **technical feasibility, systems integration, and human** usability. Unlike greenfield contexts, where new architectures can be defined freely, brownfield overlays must operate entirely within the constraints of existing electronic control units (ECUs), communication buses, and certification boundaries (Madni, A., & Sievers, M. (2021) and ISO/IEC/IEEE. (2015). 15288)

The proposed framework builds on three principles:

1. **Reuse of Subsystem Signals.** Legacy subsystems already publish a wealth of information, such as suspension height, tyre pressure, tow-bar deployment, and peripheral states. These signals form the input domain for overlays, avoiding the cost and risk of introducing new hardware (Ganesh, D. Y (2022)).

2. **Lightweight Computational Overlays.** Subsystem signals are transformed into higher-level geometry parameters such as ground clearance, approach angle, departure angle, and break- over angle. These computations are deliberately lightweight and structured for real-time execution, ensuring responsiveness within strict timing budgets (MathWorks. (2022)).

3. **Human–Machine Interface (HMI).** Outputs are presented to operators through dual modalities: numerical values for engineering precision and graphical visualisations for rapid comprehension. This ensures that information is not only accurate but also actionable in operational contexts (RTCA. (2011)).

Implementation with Model Based Engineering (MBE). The framework is implemented using MBE supporting architecture design, executable modelling, and simulation prior to deployment (INCOSE (2023). In this work, MATLAB/Simulink was used to model subsystem interactions and overlay computations, enabling a seamless transition from simulation to prototype ECU integration (MathWorks. (2022)).

Assurance via staged V&V. Verification and validation follow a progressive workflow aligned with systems-engineering standards (INCOSE (2024), and ISO/IEC/IEEE. (2015). 15288): Software-in-the-Loop (SIL) for equation correctness, Hardware-in-the-Loop (HIL) for real-time ECU integration, and Human-in-the-Loop (HITL) for usability and comprehension.

Standards alignment and incremental modernisation. By embedding the framework within established systems-engineering standards and principles such as (INCOSE, (2023), ISO/IEC/IEEE 15288:2015, 2015, and INCOSE (2024)), the approach demonstrates how brownfield systems can be modernized incrementally. Rather than requiring wholesale redesign, overlays enable progressive digital transformation, improving safety and usability while preserving certification and architectural integrity (INCOSE. (2023) and ISO/IEC/IEEE. (2015). 15288 and INCOSE. (2024).

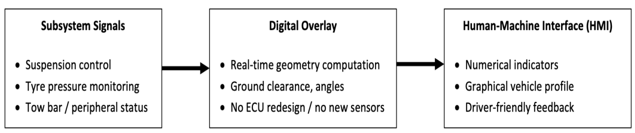


Figure 1: Framework for Brownfield Digital Overlays: Legacy ECU signals are processed

through a computational overlay and presented via a dual-mode HMI, with validation supported by SIL, HIL and HITL (Ganesh . D. Y (2022), MathWorks. (2022) and RTCA.(2011))

As shown in Figure 1, signals from legacy ECUs are processed through a computational overlay and displayed via a dual-mode Human-Machine Interface (HMI), with validation supported by SIL, HIL, and HITL (Ganesh, D. Y (2022), MathWorks. (2022) and RTCA. (2011))

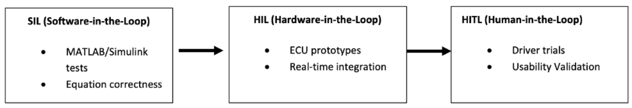


Figure 2: Progressive Verification and Validation Workflow: System testing advances from SIL, HIL and HITL, covering simulation, hardware integration and human trials (Ganesh . D. Y (2022), MathWorks. (2022) and RTCA.(2011)).

Technical Implementation

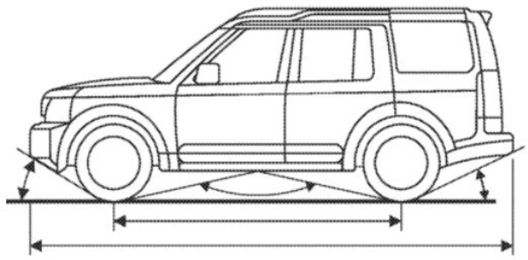
The Vehicle Geometry overlay was developed to transform legacy subsystem signals into actionable safety information without requiring new sensors or hardware redesign. Its implementation followed a sequence from subsystem signal modelling, through geometry computation, to runtime integration with the human–machine interface (HMI), and finally to progressive verification and validation.

Subsystem Signal Modelling

The overlay relied exclusively on signals available from existing subsystems, ensuring compatibility with entrenched Electronic Control Units (ECUs) and communication buses. Key inputs included: suspension control modes (access, standard, off-road, extended), tyre pressure monitoring values, tow-bar deployment status, and peripheral configurations such as mirrors or side steps. These signals, accessed via the Controller Area Network (CAN) bus, defined the system's input domain. Importantly, no additional sensors were introduced, maintaining compliance with certification and brownfield constraints ((ISO/IEC/IEEE. (2015). 15288).

Geometry Computation

From the available subsystem signals, four parameters were derived to characterise the vehicle's geometry envelope: ground clearance (GC), approach angle (AA), departure angle (DA), and break- over angle (BOA) (Figure 3). Each was expressed using lightweight trigonometric equations, enabling continuous computation within <200 ms latency (MathWorks. (2022)).



- *GC* = f(suspension height, tyre pressure correction)
- *AA* = clearance at the front axle relative to overhang
- *DA* = rear clearance adjusted for tow-bar deployment
- *BOA* = mid-vehicle clearance relative to wheelbase

These computations produced a continuously refreshed geometry model interpretable by drivers in real time (Figure 3).

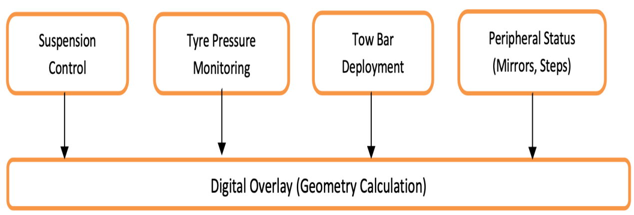


Figure 3: Geometry parameters derived from subsystem signals showing how suspension control, tyre pressure monitoring, tow-bar deployment, and peripheral status feed into the digital overlay for geometry calculation (Ganesh, D. Y (2022), Mathworks. (2022)).

These equations were lightweight enough for execution within existing ECU capacity, with updates occurring in under 200 ms. The result was a continuously refreshed "geometry envelope" that translated raw subsystem states into operability relevant safety information.

Integration and HMI

The overlay architecture (Figure 4) processes subsystem signals, computes geometry, performs plausibility checks, and publishes outputs to the central display (MathWorks (2022)).

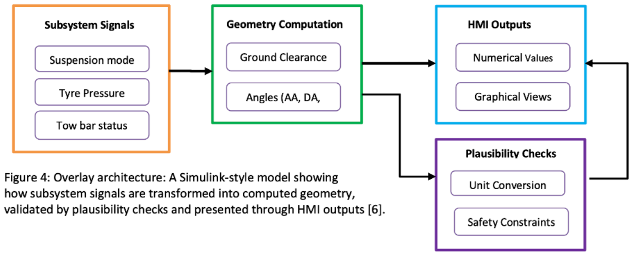


Figure 4: Overlay architecture: A Simulink-style model showing how subsystem signals are transformed into computed geometry, validated by plausibility checks and presented through HMI outputs (Mathworks. (2022)).

As shown in Figure 4, subsystem inputs are mapped to computation blocks, with plausibility checks ensuring correct unit conversions and compliance with safety constraints. The outputs are presented through a dual-mode HMI (Figure 5): numerical indicators for precision and a graphical vehicle profile for rapid comprehension. This combination balances accuracy with usability, consistent with human factors guidance for safety-critical contexts (INCOSE. (2024).

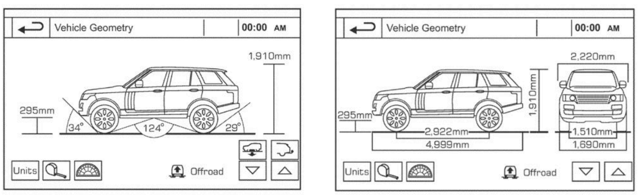


Figure 5: Dual-mode HMI outputs for vehicle geometry overlay. Numeric values and graphical cues are combined to support both precision and situational awareness (INCOSE (2023) and RTCA (2011)).

Verification and Validation (V&V)

Verification and Validation (V&V) were conducted to ensure that the proposed overlay architecture met functional, integration, and usability requirements. Verification focused on confirming correctness of equations, robustness of real-time integration, and compliance with system constraints, while validation addressed driver usability and decision-making accuracy. The staged V&V process followed the progressive workflow outlined in Figure 2, moving from simulation (SIL) to hardware integration (HIL), and ultimately to Human-in-the-Loop (HITL).

Verification was staged, following the progressive workflow outlined in Figure 2:

- Software-in-the-Loop (SIL): MATLAB/Simulink tests confirmed equation correctness (MathWorks. (2022)).
- Hardware-in-the-Loop (HIL): Prototype ECUs validated real-time integration under CAN bus load (ISO/IEC/IEEE. (2015). 15288).
- Human-in-the-Loop (HITL): Simulator trials showed >95% correct driver decisions, with ~1 s comprehension latency (Table 1) (Ganesh.D. Y (2021) and INCOSE. (2024)).

Table 1: SIL and HIL verification results for geometry computations

Verification Stage	Mean Latency (ms)	Maximum Latency (ms)	Compliance
SIL (Simulink)	145	180	Pass (<200 ms)
HIL (Prototype ECU)	160	195	Pass (<200 ms)

As shown in Table 1, measured results confirm that overlay computation consistently update within 200 ms across both SIL and HIL stages, meeting real-time performance requirements.

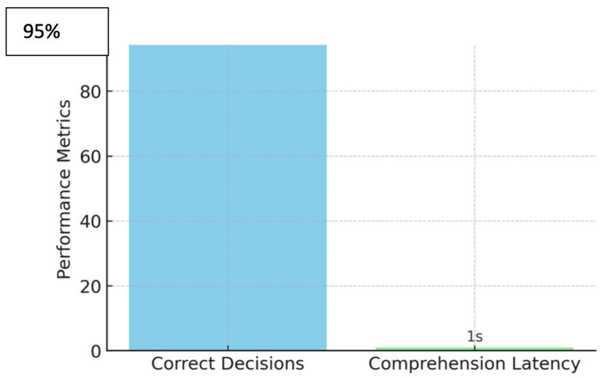


Figure 6: Human-in-the-Loop (HITL) trial outcomes: Drivers achieved >95% correct navigation decisions with ~ 1 s comprehension latency (INCOSE. (2024)).

Finally, Human-in-the-Loop (HITL) simulator trials showed that drivers interpreted overlay outputs within approximately one second and achieved more than 95% correct navigation decisions (Figure 6). This staged approach is consistent with the SEBoK guidance on progressive validation (INCOSE. (2024)).

Together, these results demonstrate that digital overlays can achieve technical rigour and operational credibility, providing a certifiable modernisation pathway in line with INCOSE's digital engineering vision (INCOSE. (2023), and ISO/IEC/IEEE. (2015). 15288).

Case Study: Vehicle Geometry

The Vehicle Geometry overlay provides a concrete demonstration of the proposed framework within a brownfield automotive platform. Its purpose was to give drivers real-time awareness of ground clearance, approach angle, departure angle, and break-over angle without requiring the addition of new sensors or the redesign of certified ECUs. (Ganesh, D. Y. (2022). and INCOSE. (2023) and ISO/IEC/IEEE. (2015). 15288).

The need for such a capability arose from recurring operator challenges: in off-road contexts, steep inclines frequently resulted in underbody strikes due to misjudged approach angles, while in urban environments, tight ramps in multi-storey car parks posed similar risks. Although subsystem signals relevant to these scenarios were already present on the Controller Area Network (CAN) bus, they were not exposed to drivers in a usable form. The overlay bridged this gap by repurposing existing data into actionable information for safe navigation.

Figure 7 presents a storyboard linking operator scenarios, overlay computations, and HMI outputs, ensuring traceability from user needs through to implementation. It shows how subsystem signals are repurposed into vehicle geometry parameters—ground clearance (GC), approach angle (AA), departure angle (DA), and break-over angle (BOA)—which are then delivered via a dual-mode HMI and validated through a staged SIL–HIL–HITL workflow (INCOSE. (2023) and ISO/IEC/IEEE. (2015). 15288).

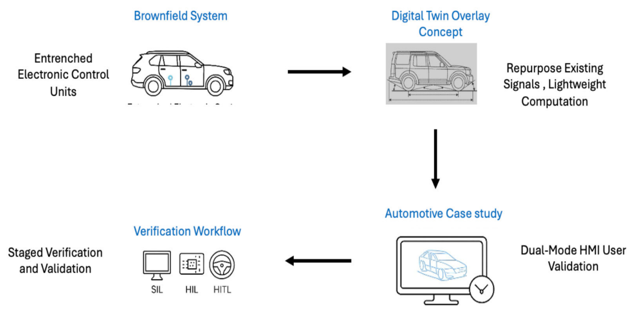


Figure 7: Digital Twin overlays for Brownfield Systems: Storyboard illustrating the Vehicle Geometry case study. Entrenched ECU signals are repurposed through lightweight computation, validated via staged SIL, HIL, HITL workflows, and delivered to drivers through a dual-mode HMI (Ganesh, D. Y (2022)).

Implementation: Implementation was strictly constrained by brownfield realities. Only existing CAN bus signals were used, including suspension modes, tyre pressures, and tow-bar deployment status (Ganesh, D. Y (2022)) and ISO/IEC/IEEE. (2015). 15288). From these inputs, the overlay calculated four geometry parameters—ground clearance, approach angle, departure angle, and break-over angle using lightweight trigonometric equations (Figure 3) (MathWorks (2022)). Computations were executed in under 200 ms, enabling continuous updates that drivers could act upon in real time. Outputs were delivered through a dual-mode human–machine interface (HMI), which combined numerical indicators for precision with a graphical vehicle profile for rapid comprehension (Figure 5) (INCOSE (2024)) and RTCA (2011). This design balanced engineering accuracy with situational usability.

Constraints and Trade-offs: The design process was further shaped by several constraints. No additional sensors could be added; computations had to run within 200 ms; drivers were expected to interpret outputs within one second; and CAN bus timing had to be preserved (ISO/IEC/IEEE. (2015). 15288). These requirements demanded specific trade-offs, including the filtering of noisy tyre pressure data and conditional adjustments for tow-bar deployment in departure angle calculations. Such choices formalised in the Vehicle Geometry overlay and protected under (UK IP. (2015) highlight the compromises necessary to deliver both technical feasibility and operator usability in legacy architectures (MathWorks. (2022) and INCOSE. (2024).

Verification and Validation: Verification followed the progressive assurance chain introduced in the framework (Figure 2) (INCOSE. (2023), ISO/IEC/IEEE 15288:2015, 2015) Software-in-the-Loop (SIL) testing in MATLAB/Simulink validated the mathematical correctness of the equations (MathWorks. (2022)). Hardware-in-the-Loop (HIL) trials then confirmed real- time integration with prototype ECUs under CAN bus timing constraints, demonstrating consistent updates within 200 ms (Table 1) (ISO/IEC/IEEE. (2015). 15288and MathWorks. (2022)). Finally, Human-in-the-Loop (HITL) simulator trials tested operator comprehension, showing that drivers interpreted overlay outputs within approximately one second and achieved more than 95% correct navigation decisions (Figure 6), (INCOSE, SEBoK, 2024). This staged approach linked equation validity, hardware feasibility, and human usability into a coherent assurance pathway.

Outcomes and Lessons: Building on the progressive verification results and HITL outcomes, the case study confirms the viability of digital twin overlays for safety-critical brownfield modernisation. The overlay improved safety by making hidden clearance limits visible, demonstrated feasibility by delivering continuous real-time performance without hardware changes, and achieved trustworthiness via progressive validation aligned with established systems-engineering standards (INCOSE. (2023), ISO/IEC/IEEE 15288:2015, 2015). Collectively, the case study validates overlays as a practical, certifiable strategy for incremental modernisation, with lessons and transferability applicable not only to automotive but also to aerospace, defence, and rail domains (INCOSE, (2023)), RTCA. (2011) and CENELEC. (2011)).

Discussions and Lessons Learned

The Vehicle Geometry overlay illustrates how brownfield systems can be enhanced through digital twin overlays, and its significance extends beyond a single automotive feature. This case study demonstrates that even legacy subsystems, originally designed for narrow and siloed purposes, can be repurposed to deliver new safety and usability value. This confirms that signal reuse is not only technically feasible but also strategically valuable, since it avoids costly hardware redesign and reduces certification overhead (Ganesh, D.Y (2022)) and (ISO/IEC/IEEE 15288:2015, 2015). By unlocking latent information already present on the bus, overlays extend the life and capability of platforms without undermining system integrity, with the originality of the approach further recognised through (UK, 2015).

An equally important lesson lies in the assurance pathway. The progressive sequence of Software-in- the-Loop (SIL), Hardware-in-the-Loop (HIL), and Human-in-the-Loop (HITL) testing proved essential for establishing confidence in both technical correctness and operational usability. Each stage built upon the previous one: SIL validated mathematical accuracy, HIL demonstrated integration with prototype ECUs under real-time bus constraints, and HITL confirmed that drivers could reliably interpret and act on the overlay outputs. This staged approach demonstrates how overlays can combine rigour with usability, offering a pragmatic assurance strategy in domains where certification restrictions make full redesign infeasible (INCOSE. (2023), ISO/IEC/IEEE 15288:2015, 2015), INCOSE. (2024)).

The broader implications extend across safety-critical domains. In defence applications, overlays could interpret terrain and subsystem signals to improve operator situational awareness without altering certified avionics. For example, existing vehicle dynamics and navigation signals could be repurposed to compute roll or pitch stability margins in off-road manoeuvres, providing commanders with actionable safety insights. In aerospace, overlays could transform avionics health or environmental data into predictive maintenance indicators or pilot advisories while remaining compliant with DO- 178C certification requirements [8]. In rail, overlays could reuse existing braking and track signals to compute real-time stopping distance margins aligned with EN 50128 standards [9], thereby enhancing safety in degraded conditions without requiring new control hardware. These examples demonstrate that the overlay methodology is not confined to automotive systems but offers a generalisable pathway for incremental modernisation across multiple domains.

Despite their differences, these industries share the same fundamental challenge: modernisation must occur without disrupting entrenched certification, cost, and hardware structures.

Finally, the case study highlights strong alignment with the INCOSE Digital Engineering Vision (INCOSE. (2023)). It demonstrates that Model-Based Engineering (MBE) and progressive verification workflows can be applied incrementally, not only in greenfield contexts. Limitations must also be acknowledged: overlays remain bounded by the fidelity of existing signals, require careful management of bandwidth and timing to avoid interference with certified functions, and depend on available computational headroom in legacy ECUs. These realities point to the need for developing reusable overlay patterns and embedding them into digital engineering toolchains to support certification frameworks that regulators can adopt (ISO/IEC/IEEE 15288:201, 2015 and INCOSE. (2024)).

These lessons, together with the acknowledged constraints on signal fidelity, computational headroom, and human factors, provide a balanced foundation for the concluding remarks and highlight where future work must focus.

Conclusion

This paper has introduced a framework for digital twin overlays that enable incremental modernisation of brownfield systems. By reusing legacy subsystem signals and applying lightweight computational models, overlays provide a certifiable pathway to improving safety and usability without hardware redesign. The Vehicle Geometry overlay demonstrated feasibility in the automotive domain, achieving real-time performance with sub-200 ms updates and supporting >95% correct operator decisions in Human-in-the-Loop trials (Figure 6, Table 1).

Looking ahead, future work should focus on three priorities. First, developing robustness strategies to manage degraded or missing signals. Second, establishing certification pathways that extend beyond standards alignment toward regulator-endorsed overlay patterns in domains such as aerospace (DO- 178C) and rail (EN 50128). Third, addressing long-term maintenance, ensuring overlays remain effective as platforms evolve over decades. Cross-domain studies across defence, aerospace, and rail will further validate transferability.

By formalizing overlays within systems engineering practice and embedding them into digital engineering toolchains, brownfield modernisation can progress from ad-hoc innovations to repeatable, certifiable patterns. In this way, overlays offer a practical route to bridging entrenched architectures with modern digital expectations, unlocking new value from systems that must remain in service for decades. In doing so, overlays not only extend the operational life of legacy systems but also chart a practical pathway toward the INCOSE vision of digitally engineered, continuously evolving, and certifiable systems-of-systems.

Acknowledgement

This work was undertaken independently through InSyE (Innovative Systems Engineering) and is self- sponsored.

References

CENELEC. (2011). EN 50128: Railway applications – Software for railway control and protection.

Ganesh, D. Y. (2022). Digitally enabled engineering systems. In Proceedings of ASEC UK.

Grieves, M. (2019). Virtually perfect: Driving innovative and lean products through digital twin technology.

INCOSE. (2023). Vision 2035: The systems engineering vision. International Council on Systems Engineering.

INCOSE. (2024). Systems engineering body of knowledge (SEBoK) (Version 2.9).

ISO/IEC/IEEE. (2015). 15288: Systems and software engineering — System life cycle processes.

Madni, A., & Sievers, M. (2021). Digital twin driven model-based systems engineering. In Proceedings of the INCOSE International Symposium.

MathWorks. (2022). MATLAB/Simulink for model-based design documentation.

RTCA. (2011). DO-178C: Software considerations in airborne systems and equipment certification.
Tao, F., Zhang, M., Nee, A. Y. C., et al. (2022). Digital twin for manufacturing and brownfield systems. IEEE Access, 10, 2345–12360.
UK. IP (2015). Intellectual Property Office. (2015). Patent GB2525043A.

Biography

Deepaa Yoharani Ganesh is the Director and CEO of InSyE (Innovative Systems Engineering), a startup focused on advancing digital and model-based systems engineering. She serves as INCOSE Chair for the Systems and Software Interface Working Group (SaSiWG) and is an advisor and industrial lecturer on the MSc Applied Systems Engineering programme at Cranfield University, UK. She works full-time in the defence sector as a Technical Lead and Systems Application Architect. Her professional experience spans research, product development, and advanced systems integration across Europe, Southeast Asia, and the UK. She is also actively involved in mentoring and coaching women in engineering through academic and professional networks. The work presented in this paper was undertaken independently through InSyE and is self-sponsored