From Parts to Systems: The Evolution of Composite Design.

AUTHOR: NICK HENRY
Business Development Manager
L&L Products

ABSTRACT

For decades, composite development focused primarily on material substitution. Composites offered engineers a lightweight alternative to traditional materials while maintaining required structural performance.

Today, the challenges facing transportation manufacturers have evolved. Weight reduction remains important, but it is now accompanied by requirements for improved thermal management, acoustic comfort, manufacturing efficiency, durability, sustainability, and occupant experience.

As a result, composite design is undergoing a fundamental transition. Rather than serving as individual lightweight components, next-generation composite solutions are increasingly being engineered as integrated systems capable of delivering multiple functions simultaneously.

This paper explores the evolution from single-function composite parts to multifunctional composite systems and examines how this shift is influencing transportation engineering.

INTRODUCTION

Transportation manufacturers are operating in an increasingly complex engineering environment.

Heavy-duty vehicles, buses, off-highway equipment, rail platforms, and emerging mobility solutions must simultaneously address:

- Weight reduction
- Energy efficiency
- Noise mitigation
- Thermal management
- Durability
- Production efficiency
- Sustainability targets

Historically, these requirements were addressed through separate components.

For example:

Function	Typical Solution
Thermal Protection	Insulation Panel
Acoustic Absorption	Fiber Mat
Structural Support	Reinforcement Component
Appearance	Cover Panel

This approach often results in:

- Increased part count
- Additional weight
- Greater assembly complexity
- Packaging challenges
- Higher system costs

The industry is now beginning to adopt a different philosophy: integrating multiple functions into fewer components.

THE EVOLUTION OF COMPOSITE DESIGN

Phase 1: Material Substitution

Early composite adoption focused primarily on replacing metal components.

Primary objectives:

- Weight reduction
- Corrosion resistance
- Design flexibility

Success was typically measured through:

- Mass savings
- Mechanical performance
- Cost comparisons

Phase 2: Functional Optimization

As composite technologies matured, engineers began incorporating additional functionality : Enhanced durability, Improved crash performance, Corrosion protection, Improved fatigue resistance for example. At this stage, composites were no longer simply replacing materials. They were improving part performance.

Phase 3: System Integration

Today, a third phase is emerging. Engineers increasingly evaluate components based on their contribution to the entire vehicle system.

Questions have shifted from:

“Can this component be lighter?” to “How many system requirements can this component satisfy simultaneously?” This represents a significant change in design philosophy.

WHY SYSTEM-LEVEL THINKING MATTERS

Modern vehicle development is increasingly constrained by competing requirements.

A design change intended to improve one performance metric can negatively affect another.

Examples include:

Objective	Potential Trade-Off
Improved Thermal Insulation	Added Weight
Better Acoustics	Increased Thickness
Structural Rigidity	Manufacturing Complexity
Durability	Cost Increase

Multifunctional composite systems offer an opportunity to reduce these trade-offs by combining multiple performance attributes within a single architecture.

MULTIFUNCTIONALITY IN THERMAL AND ACOUSTIC APPLICATIONS

Under-cab and engine compartment environments provide a strong example of the industry’s transition toward system-level composite design.

These applications typically require:

- Thermal insulation
- Acoustic attenuation
- Structural durability
- Resistance to environmental exposure
- Low mass

Historically, multiple materials were layered together to achieve these requirements.

Newer composite architectures allow these functions to be integrated into a single engineered panel system.

This approach can reduce part count, assembly complexity, vehicle mass, while improving overall performance.

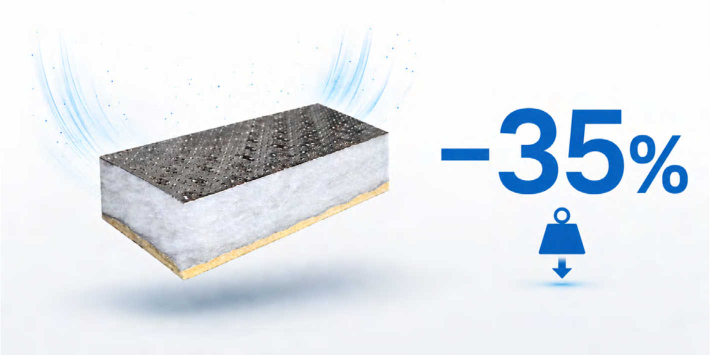

Figure 1. *Mass Reduction Comparison: ~35% of mass reduction for the thermal acoustic system*

THERMAL PERFORMANCE AS A SYSTEM REQUIREMENT

Thermal management is becoming increasingly important across transportation applications.

Key drivers include:

- Higher operating temperatures
- Increased system density
- Alternative powertrain architectures
- Driver comfort expectations

Effective thermal barriers contribute to:

- Improved occupant comfort
- Protection of adjacent systems
- Packaging flexibility

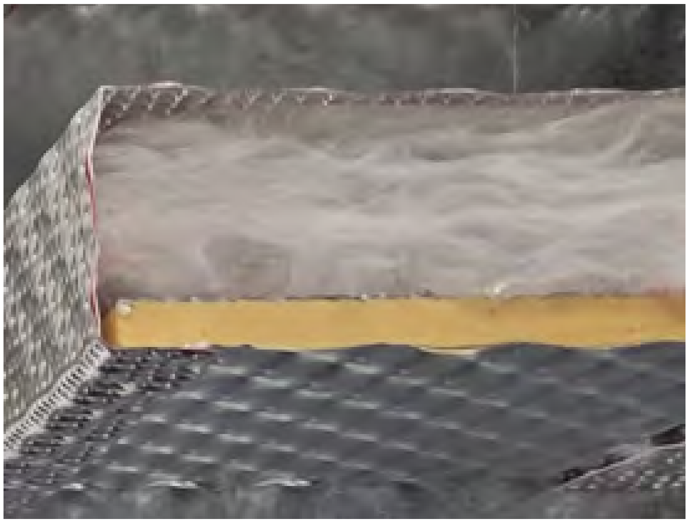

Figure 2. *Edge of InsituCore® thermal and acoustic panel*

ACOUSTIC PERFORMANCE BEYOND NOISE REDUCTION

Acoustic engineering is increasingly recognized as a contributor to:

- Driver comfort
- Reduced fatigue
- Vehicle quality perception

The challenge is particularly significant in commercial transportation, where low-frequency powertrain noise can be difficult to manage.

Rather than relying solely on additional absorptive materials, multifunctional panel architectures can incorporate acoustic functionality directly into the component design.

This enables acoustic performance to become part of the structural system rather than an added feature.

THE FUTURE OF COMPOSITE DESIGN

The next generation of composite innovation may not be defined solely by lighter materials or stronger structures. While these attributes remain critical, the industry's focus is expanding toward a broader measure of value. Manufacturers increasingly expect materials and components to contribute to multiple performance objectives simultaneously. As a result, success is becoming less about optimizing a single characteristic and more about how effectively a solution integrates functionality, simplifies systems, supports efficient design, and improves manufacturing processes across the vehicle lifecycle.

This shift reflects a fundamental evolution in engineering priorities. Rather than addressing thermal management, acoustics, structural performance, and durability through separate components, engineers are seeking opportunities to combine these functions within integrated systems. Multifunctional composite architectures enable a more holistic approach, helping reduce complexity while maintaining or enhancing overall vehicle performance.

Looking ahead, future composite systems may routinely combine structural support, thermal insulation, acoustic management, fire protection, energy absorption, and aesthetic considerations within a single engineered component. This convergence of functions has the potential to reduce part counts, streamline assembly, improve packaging efficiency, and create greater value at the vehicle level.

As transportation manufacturers continue to pursue higher levels of efficiency, performance, and sustainability, the ability to consolidate multiple requirements into fewer, more capable components will become an increasingly important differentiator. The future of composite design will not simply be about replacing traditional materials. It will be about creating integrated systems that enable engineers to achieve more with less.

CONCLUSION

Composite design is evolving from a focus on individual parts to a focus on integrated systems.

While lightweighting remains important, manufacturers increasingly require materials and components that deliver multiple benefits simultaneously. Thermal management, acoustic comfort, structural performance, durability, and manufacturing efficiency can no longer be evaluated independently.

The future of composites lies not simply in replacing traditional materials, but in enabling multifunctional systems that create greater value at the vehicle level.

As transportation platforms continue to evolve, system-level composite design will play an increasingly important role in helping manufacturers meet complex performance requirements while reducing overall complexity.

NICK HENRY

Business Development Manager
L&L Products

Nick Henry has been working closely with Automotive and Commercial vehicles Europe, supporting the development and adoption of advanced material solutions for over 20 years. His experience spans lightweighting, thermal management, acoustic performance, and multifunctional composite technologies. Through collaboration with OEMs and industry partners, he helps explore how materials can support broader system-level engineering objectives and enable next-generation vehicle architectures.

Connect with Nick on LinkedIn

CONTACT

webmaster@llproducts.com