ElectronicDesign®

Why Multiphysics Simulation Matters for Next-Generation Electronics

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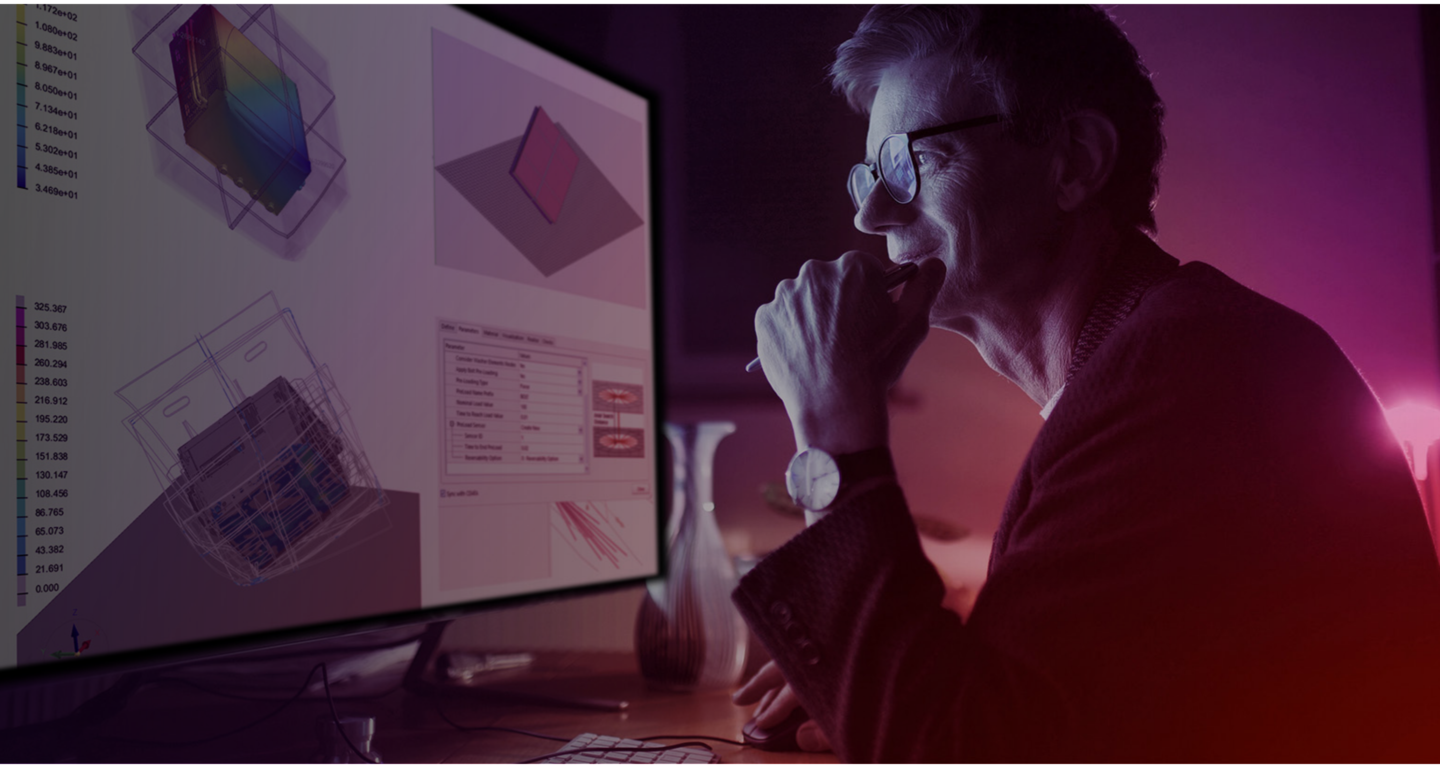
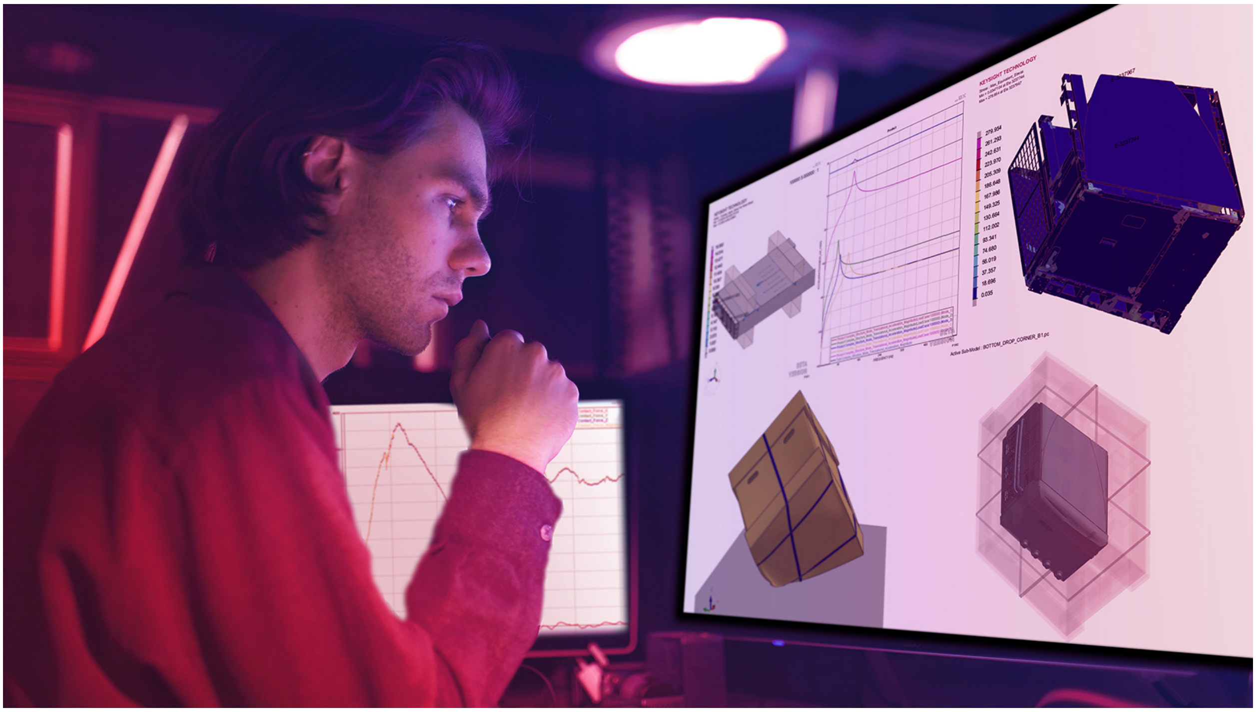


OVERVIEW

Introduction



The Promise and Power of Multiphysics Simulations

Product development is being reshaped by the drive for ever-greater performance. Across industries, engineers are expected to deliver products that consume less energy, generate less waste, and use materials more efficiently, while simultaneously providing greater functionality and performance. This challenge is particularly evident in advanced semiconductors, power electronics, and three-dimensional integrated circuits (3D-ICs).

Electronic product teams are under increasing pressure to deliver smaller, hotter, denser, and more mechanically constrained designs while moving faster, controlling development costs, and improving first-launch reliability. As chipmakers stack multiple layers of silicon and pack more transistors into smaller spaces, power density continues to rise dramatically. These compact architectures improve performance and reduce system size, but they also create complex thermal, electrical, mechanical, fluid, and electromagnetic interactions that cannot be evaluated in isolation.

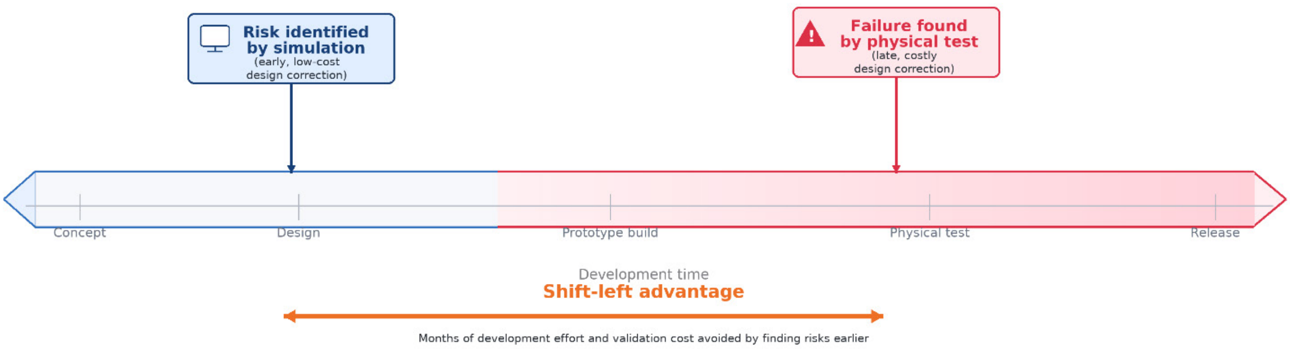


Figure 1. The Challenge

Simulation is often viewed as the answer, but many teams still rely on workflows that are too late, too disconnected, or too difficult to translate into timely design decisions as shown in the Fig 1. When thermal, shock, vibration, packaging, or reliability issues surface only during prototype testing, teams face costly redesigns, schedule delays, and avoidable product risk.

This eBook explains how a more connected multiphysics simulation approach can help electronics teams understand cross-domain interactions earlier, evaluate tradeoffs more confidently, and make better design decisions before physical testing reveals hidden issues.

Who Should Read This E-Book?

- Engineering leaders who need to reduce late-stage design risk
- Electrical, mechanical, thermal analysis, and reliability teams working on dense electronics systems
- Product managers responsible for schedule, cost, and launch readiness
- Manufacturing or quality teams that need earlier visibility into design choices that can affect reliability in the field

Multiphysics Simulation — A Path Forward

Multiphysics simulation gives electronics teams a way to understand product behavior across connected engineering domains rather than through isolated checks. By bringing together finite element analysis (FEA), computational fluid dynamics (CFD), and other physics-based methods in a shared workflow, teams can see how electrical losses create heat, how heat changes material behavior, how deformation affects solder joints, connectors, and packages, and how shock or vibration can reduce reliability. For electronics, this connected view matters from components and advanced packages to PCBs, enclosures, and full systems.

Traditional single-discipline analysis is no longer sufficient when product performance depends on tightly coupled effects. Multiphysics simulation gives engineers a more realistic view of how thermal, structural, fluid, electromagnetic, electrochemical, and material phenomena interact under real operating conditions. This helps teams identify which design tradeoffs are creating risk or degrading performance early in development, when changes are still easier and less expensive to make. Figure 2 captures such an idea of engineering without boundaries: design teams need a workflow that makes cross-domain interactions visible early

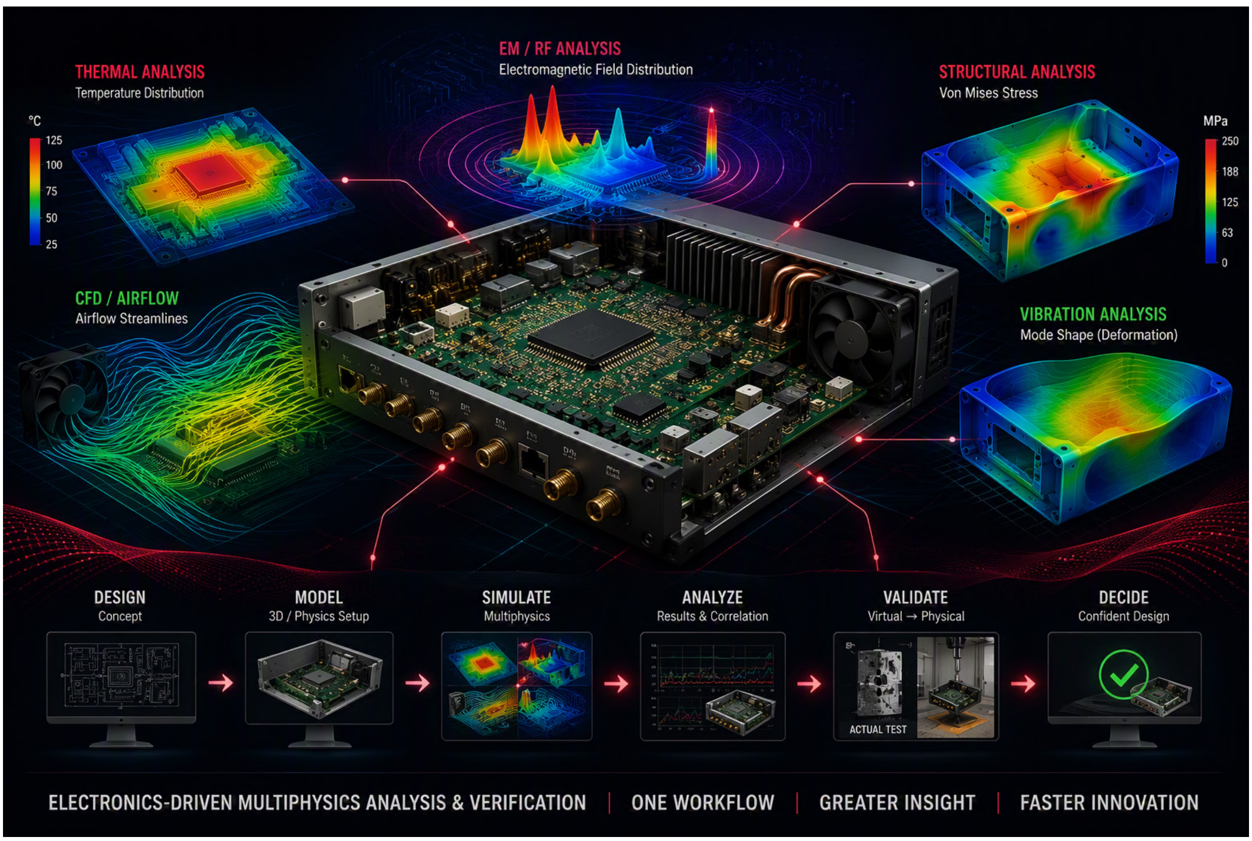


Figure 2. Engineering without boundaries

enough to influence design decisions, not after the product has already moved into physical testing.

This capability is also becoming more important as companies pursue sustainability goals. Improving efficiency often means reducing material, lowering energy consumption, extending product life, and operating closer to physical limits. In that environment, interactions between heat, airflow, structural loading, materials, and reliability become more consequential. Multiphysics simulation helps engineers optimize cooling strategies, reduce unnecessary prototypes, improve energy efficiency, and make design choices that support both product performance and sustainability objectives.

As products become more integrated, compact, and performance-driven, Multiphysics simulation is evolving from a mere engineering tool into a strategic development platform. It provides holistic insight needed to understand complex interactions across an entire system, enabling organizations to innovate faster while delivering more efficient, reliable, manufacturable, and sustainable products. The most relevant domains for Multiphysics simulation include:

- Thermal: Thermal analysis simulation predicts how heat is generated, transferred, and dissipated throughout electronic assemblies. Engineers use these analytical models to optimize heat sinks, airflow, vapor chambers, liquid cooling, and component placement while ensuring key metrics, like semiconductor junction temperatures, remain within safe operating limits for performance and reliability.

- Structur al Mechanics: Structural analysis examines how printed circuit boards, semiconductor packages, connectors, enclosures, and mounting systems respond to mechanical loads. It predicts stresses, strains, deformation, and potential failure mechanisms resulting from assembly, handling, thermal expansion, or operational loading throughout the product's life. Dynamic simulations predict how electronic products respond to vibration, mechanical shock, and impact during shipping, installation, and normal operation. They help identify resonance, excessive deflection, solder joint fatigue, connector failures, and other reliability risks before physical qualification testing.

- Fluid Dynamics: CFD models the movement of air or liquids used to cool electronic systems. These simulations optimize airflow paths, fan placement, pressure distribution, coolant flow, and heat exchanger performance to improve cooling efficiency while reducing energy consumption, noise, and thermal hot spots.

- Material Behavior: Material modeling characterizes how metals, polymers, ceramics, composites, solders, adhesives, and encapsulants respond to thermal cycling, mechanical loading, aging, creep, and fatigue. Accurate material properties improve predictions of long-term reliability, advanced packaging durability, and overall product lifetime under real-world operating conditions.

Multiphysics simulations combine these domains in a guided process, so that actionable results can be obtained faster and with fewer inputs. The value is not simply running more simulations, but in gaining a clear understanding of how these domains interact when power density, advanced packaging constraints, airflow, component placement, and mechanical loads all simultaneously influence the results, and in turn, influence product performance and reliability.

The New Reality of Electronic Product Development

Electronic products have become dramatically more capable over the past decade, but they have also become significantly more difficult to design. Engineers are expected to deliver smaller, lighter, faster, and more energy-efficient products while maintaining high reliability and reducing time-to-market. As a result, product development now requires balancing a growing number of physical factor interactions rather than simply optimizing electrical performance.

Mechanical reliability presents a notable challenge. Every electronic product must survive vibration, shock, handling, transportation, and years of daily use, yet these issues often receive relatively little attention during traditional electronic design. They typically fall outside conventional electronic design automation (EDA) workflows, while also competing for attention within mechanical and advanced packaging activities. As a result, many organizations still rely heavily or exclusively on physical prototype testing to uncover problems as shown in Figure 3.

Unfortunately, discovering cracked solder joints, damaged connectors, excessive board flexing, or enclosure failures during qualification testing as shown in Figure 4, can force expensive redesigns, delayed product introductions, and additional prototype iterations. Furthermore, the time and expense involved in physical testing tend to reduce the number of scenarios that can be practically explored, leaving many potential risks regarding durability and service life unexamined. Figure 2 provides a physical-test frame that makes this late-discovery problem concrete, while Figure 3 shows how the same problem can be represented virtually before hardware commitment.

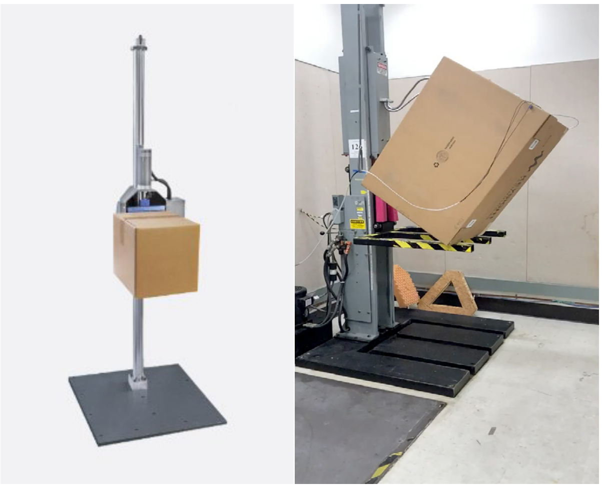


Figure 3. Simple free fall impact test apparatus for packaged products

Figure 4. Instrument Front Housing damage during physical testing

Thermal management has also grown more critical. As processors, power electronics, and high-speed communications devices generate increasing amounts of heat, designers have less physical space available for cooling solutions. Every thermal decision influence electrical performance, mechanical packaging, product reliability, manufacturing cost, and even long-term energy efficiency. Small changes in component placement, airflow, enclosure geometry, or material selection can produce unexpectedly large effects on operating temperatures and overall system performance. Margins of error that could once be taken for granted are rarely available today. Thermal considerations must be robust and sufficient for all expected use cases.

These challenges rarely occur independently. Electrical losses create heat, heat causes materials to expand, and mechanical stress can alter electrical behavior. Increasingly, successful electronic product development depends on understanding these interconnected physical phenomena early in the design process rather than discovering them after designs have been frozen and hardware has been assembled.

Organizations without the ability to fully model shock and vibration, as well as thermal concerns, risk a litany of troubles ranging from direct thermal failures to package cracking, PCB warpage, solder joint stress, component detachment, and connector failures. These issues, in turn, spell delayed product launches, premature reliability issues, and expensive field returns.

On the other hand, organizations that adopt a more integrated, physics-based approach to design can identify potential problems sooner, reduce costly prototype iterations, improve product reliability, and accelerate innovation. In today's electronics industry, understanding how multiple physical domains interact has become a competitive necessity rather than simply an engineering advantage.

Key Takeaway

Multiphysics simulation is not just a tool for analysts. It is a way for product, engineering, reliability, and manufacturing teams to make better decisions earlier, more efficiently, and with a higher likelihood of positive outcomes, at a time when design changes are less disruptive and comparatively inexpensive.

Adjusting to Reality — Why Single-Physics Simulation I s No Longer Enough

Modern engineering problems rarely belong to only one engineering domain.

Yet traditional workflows often begin with the electrical design team and then sequentially engage mechanical, thermal, and reliability engineers for validation. In practice, electronics design decisions may be completed well before shock, vibration, enclosure, packaging, or thermal risks are fully evaluated. This "over-the-wall" handoff can create inefficiencies because downstream teams are asked to validate a design after many constraints have already been locked in. When prototype testing reveals issues, teams must revisit earlier decisions, coordinate across disciplines, and redesign under schedule pressure. It makes engineering more difficult and strains organizations.

Existing computer-aided engineering (CAE) tools can also be difficult to set up, require specialized expertise, and produce results that are not always easy to connect to fast design decisions. The result is a workflow that can become slow, reactive, and costly, especially when late-stage issues arise.

As the product evolves, these issues are already interacting across physics domains, even if the workflow does not make those interactions visible. The system becomes a black box hiding its problems from view. These interactions among physics domains can affect product performance and reliability long before they are detected and fully documented.

A design that meets electrical performance targets may still be vulnerable to drops, shocks, or vibrations if mechanical loads are concentrated at a few vulnerable points. And a thermal solution that improves cooling may also change airflow paths, enclosure constraints, component placement, or mechanical stress.

These interactions show why it is critical for teams to get a connected view of product physics earlier in the design process, before prototype testing eventually exposes issues that are then expensive to correct.

Shock and Impact — Examples of Process Problems

Traditional CAE tools often produce large volumes of raw data, such as displacement plots, stress contours, and time histories, which require expert interpretation. This data, by itself, may do little to help engineering decision-makers. Instead, for system-level reliability decisions, stakeholders need concise, actionable indicators such as:

- Relative shock severity between designs,
- Location of highest load transmission, and
- Comparative response of subsystems or interfaces.

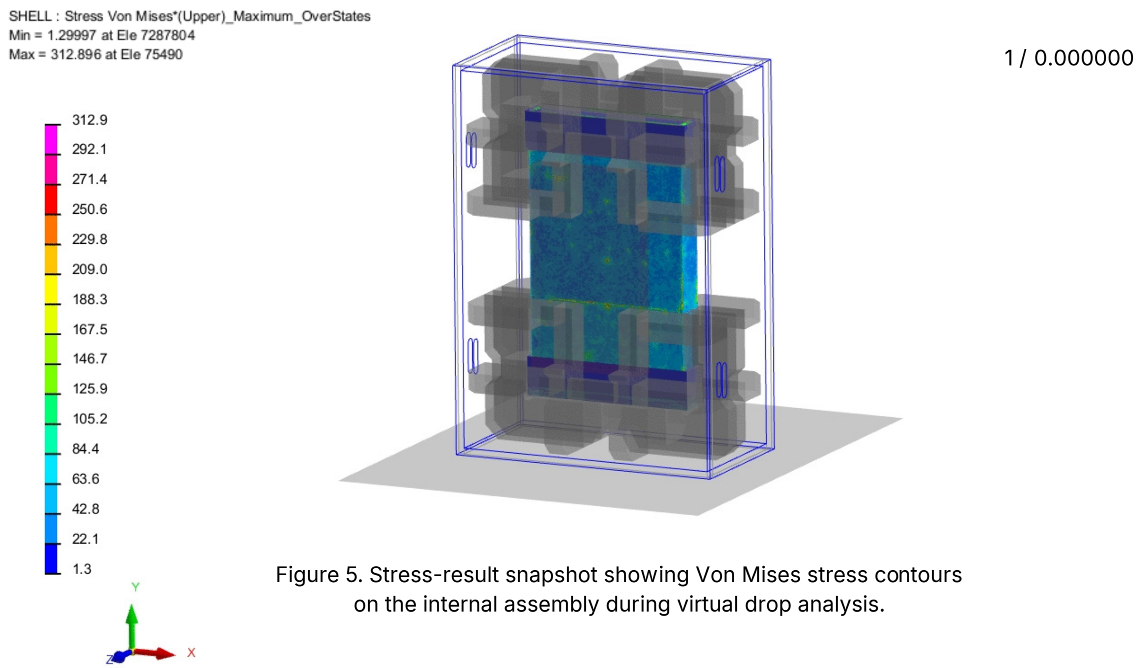


Figure 5. Stress-result snapshot showing Von Mises stress contours on the internal assembly during virtual drop analysis.

The launch snapshots in Figure 5 show how these outputs can be turned into recognizable engineering evidence rather than disconnected raw solver artifacts.

Multiphysics simulation makes possible automated, system-level shock analysis that can improve the efficiency, consistency, and timing of shock-related decision-making during product development. Rather than replacing physical testing, this approach is intended to complement, enrich, and inform the design process, helping shape test planning and allowing teams to use physical validation resources more selectively and effectively.

The Power of Multiphysics — Building a Unified Engineering Workflow

By breaking down engineering silos, Multiphysics simulation bridges design and physical validation by identifying mechanical failure risks early, reducing physical test cycles, and minimizing late-stage design rework. In fact, as a shared engineering resource, Multiphysics simulation can strengthen collaboration by providing a common framework and guided workflow for multiple disciplines throughout the product development process:

- Mechanical Engineering: Mechanical engineers can evaluate structural integrity, shock and vibration response, thermal expansion, and packaging performance within the context of the complete electronic system. This enables mechanical decisions to be made earlier and with a clearer understanding of their effects on electrical performance and long-term product reliability.
- Electrical Engineering: Electrical engineers gain insight into how heat, mechanical stress, materials, and packaging influence circuit performance, signal integrity, power delivery, and component reliability. This broader perspective allows electrical and mechanical design decisions to be optimized together rather than independently.

- Reliability Engineering: Reliability teams can predict potential failure mechanisms earlier by analyzing the combined effects of thermal cycling, vibration, mechanical loading, and material behavior. Simulation complements physical qualification testing by identifying higher-risk designs before prototypes are built and reducing unexpected field failures.

- Manufacturing: Manufacturing engineers can evaluate how assembly methods, production tolerances, solder processes, material variation, and packaging choices affect product performance and yield. Understanding these interactions earlier helps improve manufacturability while reducing costly production changes and quality issues.

- Product Management: Product managers benefit from earlier visibility into technical risks, design tradeoffs, and development progress. Better-informed engineering decisions support more realistic schedules, improved cost control, stronger confidence in product readiness, and faster responses to changing market requirements.

- Shared Simulation Data: A common simulation environment allows engineering disciplines to work from the same validated models and assumptions rather than maintaining separate analyses. Shared data improves communication, reduces duplicated effort, and promotes more consistent engineering decisions across the organization.

- Version Control: Managing simulation models, assumptions, materials, and results under formal version control ensures that engineering teams can reproduce analyses, compare design alternatives, and maintain confidence that everyone is working from the most current and approved information.

- Traceability: Comprehensive traceability links simulation inputs, assumptions, design revisions, validation activities, and final results throughout the development process. This creates a documented engineering record that supports product qualification, regulatory compliance, customer requirements, and future design improvements.

- Design Governance: Standardized workflows, reusable templates, automated reporting, and consistent review processes help organizations establish stronger engineering governance. This improves design consistency across projects, reduces reliance on individual expertise, and supports higher-quality, more repeatable product development practices.

- Templating: Multiphysics capabilities can also include off-the-shelf templates and a database of materials, which can reduce the need for expertise and specialists.

How Guided Virtual Shock Analysis Supercharges Electronics Design

Keysight Multiphysics Simulation provides a template-based, wizard-driven approach to virtual shock-and-drop analysis that incorporates established simulation practices into standardized, reusable workflows. Engineers define the product geometry, constraints, test environment, and evaluation objectives, while the workflow automates mesh generation, material assignment, load definition, solver execution, and report creation. The approach is intended to make shock-and-drop simulation more accessible to design engineers without requiring extensive CAE expertise, while producing consistent and repeatable results. Figures 8 show snapshots that support the guided workflow story.

- Guided workflow with built-in best practices: A step-by-step interface incorporates input validation and recommended default settings throughout model setup. This enables users to perform shock-and-drop analyses with a relatively short learning curve, reducing the need for detailed knowledge of solver configuration or contact modeling.

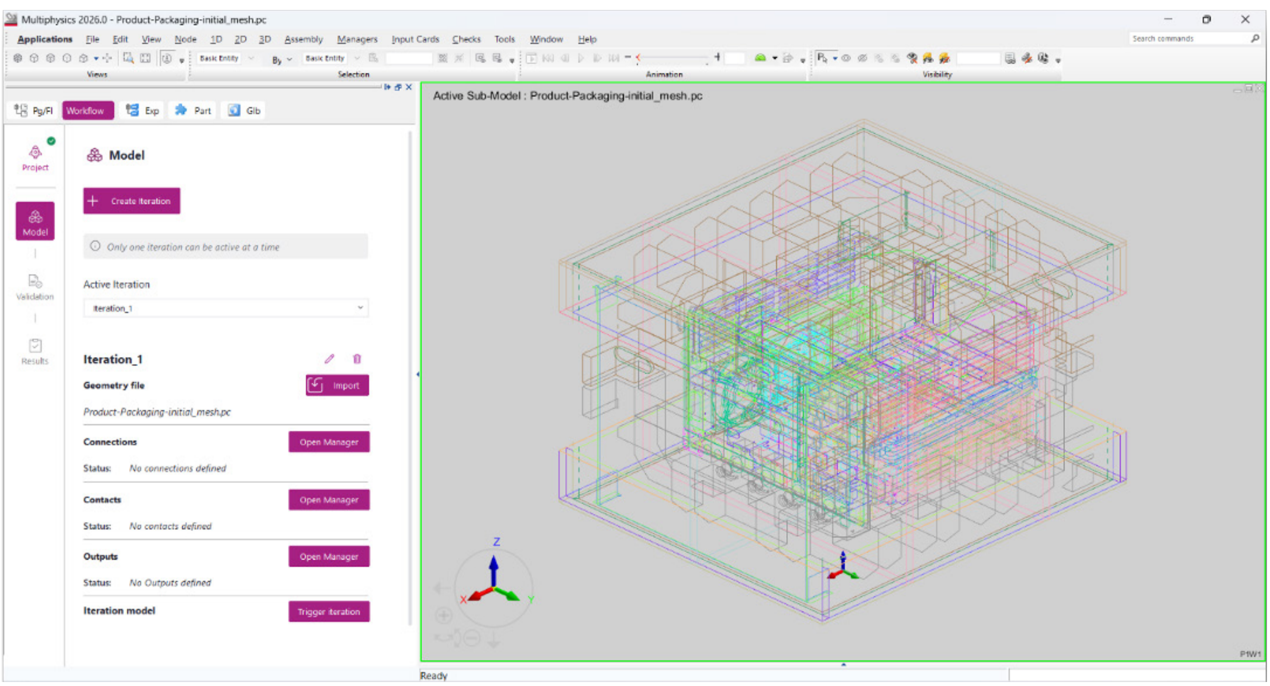


Figure 6. Guided Project Workflow

- Electronics-focused material library: A curated database includes commonly used enclosure materials, printed circuit board substrates, structural components, and packaging materials. Default material properties help streamline model preparation and reduce setup errors, while custom material models can be added as needed. The platform also supports integration with third-party material databases, such as TOTAL MATERIA™.

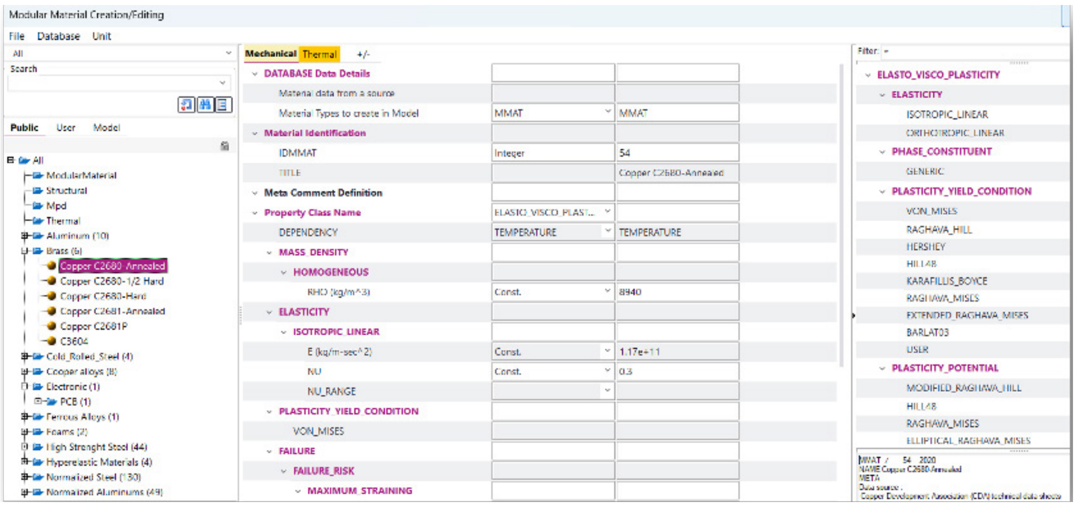


Figure 7. Electronics Specific Materials

- Centralized contact management: Assembly interactions — including contact pairs, interface definitions, and joint conditions — are defined once and reused across multiple analyses. This approach reduces repetitive setup work and promotes consistency between simulation iterations.

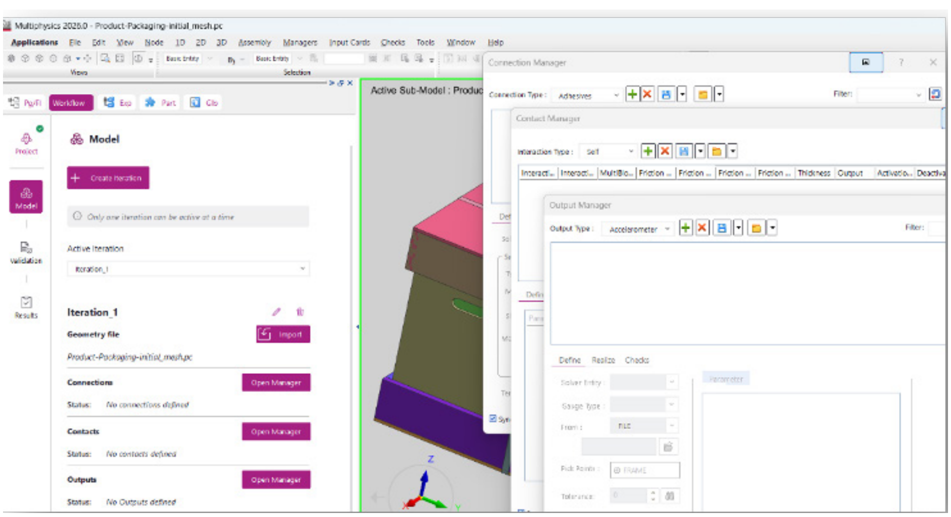


Figure 8. Centralized managers

- Templates aligned with industry test standards: Preconfigured load cases support widely used mechanical test standards, including IEC 60068-2-27 for shock testing, IEC 60068-2-31 for drop and topple testing, and spherical impact scenarios. These templates correspond to established physical test definitions, simplifying comparison between simulation results and laboratory testing.

- Validation plan automation: Predefined validation plans can be executed as a single workflow, automatically generating simulation runs, selecting scenarios, and tracking results. Multiple drop orientations, impact locations, or design alternatives can be evaluated within a common analysis framework.

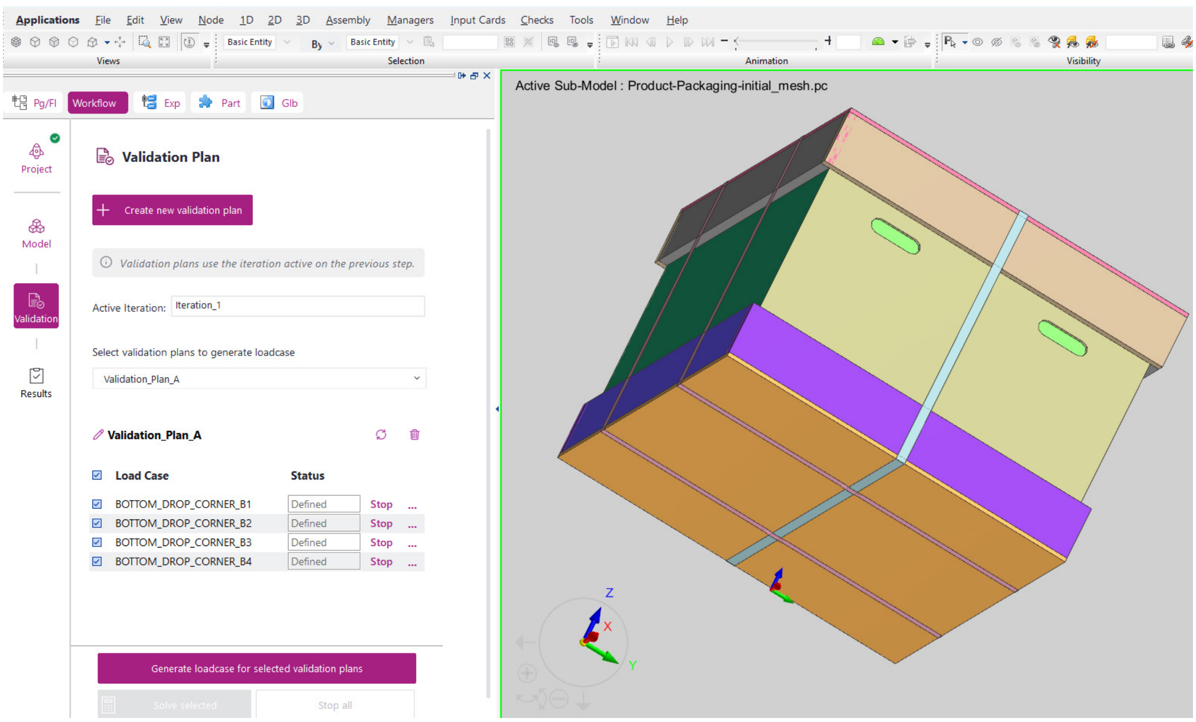


Figure 9. Application Templates

- Automated reporting and visualization: Standardized reports are generated automatically and may include acceleration-time histories, peak response values, pulse duration, and frequency-domain information. These reports are formatted for engineering reviews and product qualification documentation, reducing the need for manual post-processing.

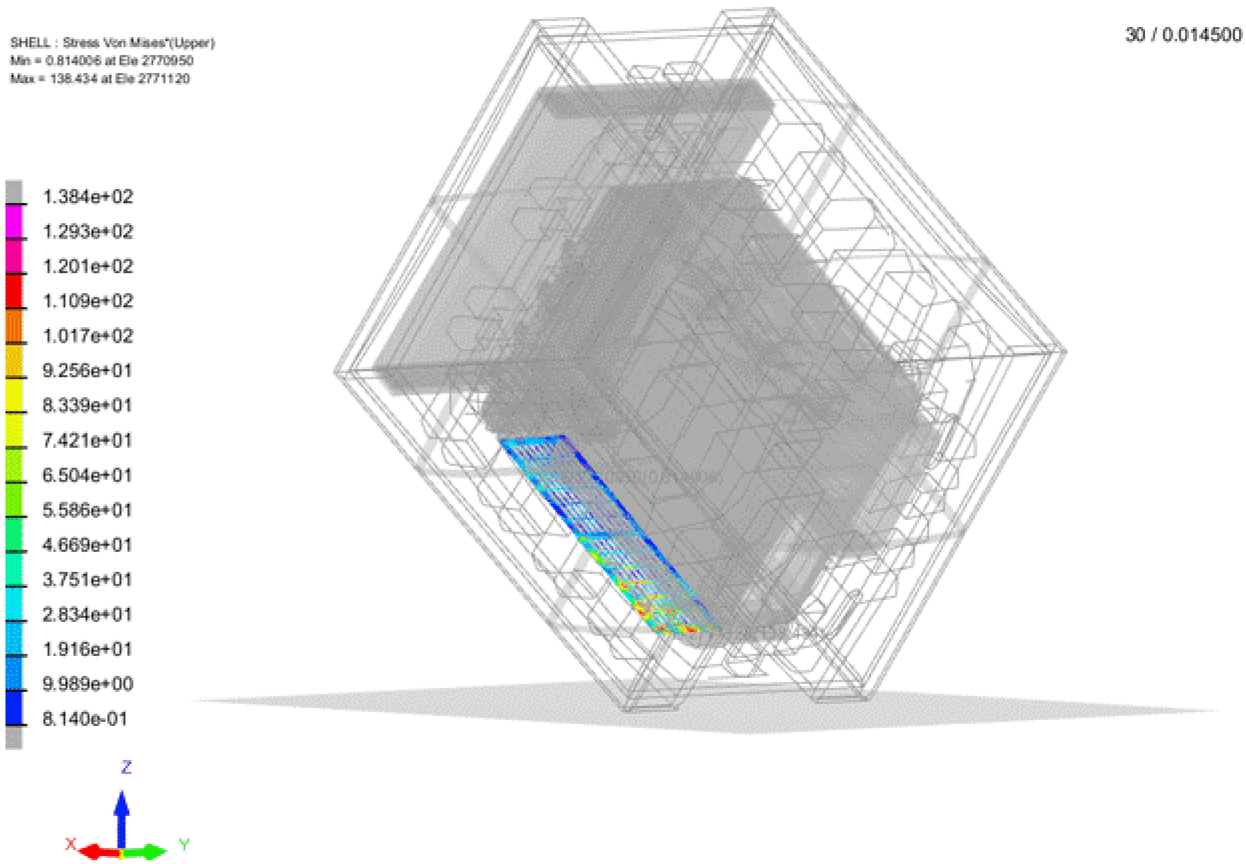


Figure 10. Results Visualization

Conclusion:

Modern electronic products operate at the intersection of electrical, thermal, mechanical, materials, and manufacturing physics. Understanding how these domains interact has become essential as devices grow smaller, more powerful, and more highly integrated. Problems that once could be addressed independently now influence one another in complex ways, making traditional, sequential engineering approaches increasingly difficult to sustain.

At the same time, the electronics industry faces intense competitive pressures. Companies are expected to shorten development cycles, control costs, improve sustainability, and deliver increasingly sophisticated products into rapidly evolving markets. Yet experienced specialists in areas such as thermal analysis, structural simulation, electromagnetics, and advanced packaging remain in limited supply. Relying exclusively on these experts to solve every design challenge through isolated analyses or late-stage prototype testing can create bottlenecks, delay product introductions, and increase development risk.

Multiphysics simulation, helping to integrate capabilities like finite element analysis (FEA), computational fluid dynamics (CFD), thermo-mechanical analysis, and structural analysis offers a more scalable approach. By allowing design teams to evaluate interacting physical phenomena earlier and more comprehensively, it helps identify potential problems before they become costly engineering changes. Engineers can explore more design alternatives, reduce dependence on multiple rounds of physical prototyping, and reserve specialized expertise for the most challenging technical questions rather than routine validation.

The business benefits extend beyond engineering. Organizations that integrate Multiphysics into everyday product development can reduce development costs, improve manufacturing readiness, increase product quality and reliability, and accelerate time-to-market. Perhaps most importantly, they gain the confidence to innovate more aggressively, knowing that design decisions are supported by a deeper understanding of real-world product behavior. In an industry where technical leadership and speed increasingly determine market success, Multiphysics simulation is becoming not simply a valuable engineering capability, but a strategic competitive requirement.

Learn more

Video: Why choose Keysight Multiphysics?

White Paper: Shifting Reliability Left: Guided Virtual Validation for Electronics Shock and Drop Testing

Product page: for Keysight Multiphysics