WHITE PAPER

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

KEYSIGHT

Executive Summary

Mechanical shock failures — discovered late in product development, after the design is frozen — are a persistent cost and schedule driver in electronics programs. Physical qualification testing remains essential, but it answers too late to guide design decisions. Traditional CAE simulation requires specialist expertise that most engineering teams cannot access at scale. Neither approach, used independently, closes the gap between early design flexibility and reliable structural qualification.

Keysight Multiphysics addresses this gap through a guided, template-based virtual shock analysis workflow accessible to design engineers without CAE specialization. Standardized validation plans execute the full drop orientation matrix as a single run, and automated reporting produces decision-ready outputs directly from the simulation environment.

Figure 1. Instrument front housing damage during physical testing

Three outcomes this enables:

- Earlier design decisions. Shock-sensitive load paths and packaging risks are identified before hardware is committed, when corrective action is least disruptive.
- Design optimization before hardware commitment. Packaging performance, housing durability, and structural response are evaluated across the full orientation matrix in a single execution, enabling virtual iteration before any prototype is built.
- Confirmed predictive capability. Physical test correlation demonstrates that the solution handles the complex multi-material assemblies and the breadth of material physics required by state-of-the-art electronics products — producing reliable predictions across the full system.

The Reliability Challenge in Electronics Development

Mechanical shock failures — cracked solder joints, fractured enclosures, damaged connectors — represent a persistent and significant cost driver in electronics product development. Electronic systems are subject to shock loading across the full product lifecycle: during manufacturing handling, logistics, installation, and end-use operation. Field returns and qualification failures attributed to mechanical shock routinely generate redesign cycles, requalification efforts, and schedule impacts that propagate across development programs.

Physical shock testing is the established qualification mechanism. Drop tests, tilt drops, ball impact tests, and packaged-product drop tests are conducted to verify compliance with internal specifications and industry standards including IEC 60068-2-27 and IEC 60068-2-31. Physical testing provides direct, authoritative evidence of system robustness under realistic loading conditions. However, its structural position in the development process limits its value as a design guidance tool: qualification testing is executed after the design is largely frozen.

At the point of test execution, enclosure geometry, internal component layout, and packaging configuration offer limited flexibility for modification. A failure at this stage initiates a corrective action cycle — root cause investigation through teardown and inspection, conservative design adjustment based on empirical judgment, prototype rebuild, and re-test — each iteration consuming days to weeks and incurring direct costs in the range of hundreds to thousands of dollars per variant, exclusive of schedule delay costs.

Physical testing also provides limited diagnostic resolution. Pass/fail outcomes confirm whether damage occurred but offer little quantitative insight into load path distribution, margin against failure, or the relative contribution of individual design features to the observed response. As a result, corrective actions are often broad and conservative, adding margin rather than targeting the specific mechanism of failure.

Physical testing remains an essential element of product qualification and cannot be replaced by simulation alone. The limitation is not the method itself but its position in the development process: absent complementary upstream analysis, shock-related design risks are not surfaced until late-stage hardware verification, where the cost and time to address them are highest.

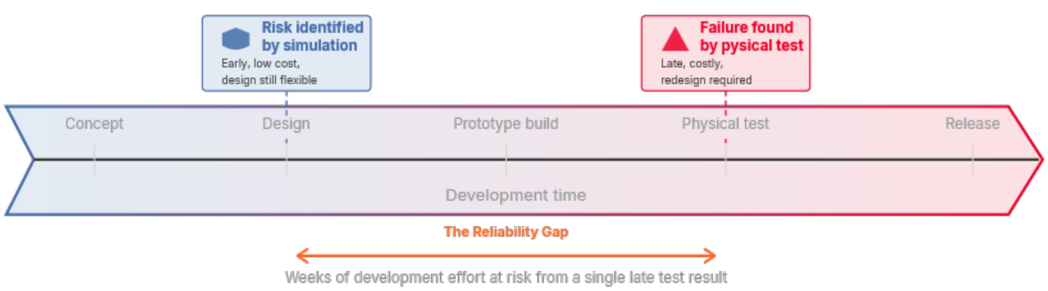


Figure 2. Product development timeline showing when shock-related failures are discovered (late, at physical test) versus when they could be identified with earlier virtual analysis.

Why Existing Approaches Don't Scale

Computational simulation is the natural complement to physical testing — capable of providing quantitative shock response data before hardware exists. In practice, traditional CAE workflows introduce barriers that prevent adoption outside a small group of specialists.

High expertise barrier. Accurate shock simulation requires specialist knowledge in transient dynamics, explicit solver configuration, contact modeling, and numerical stability — restricting analysis to a few individuals and creating organizational bottlenecks.

Manual, time-intensive setup. Each test scenario requires substantial preparation: geometry cleanup, contact definition, material assignment, and solver configuration. Reconfiguring for a new test condition or design variant is a significant rework effort, making design exploration impractical within typical program timelines.

Inconsistent assumptions. Without standardized templates, inputs vary by analyst and program — shock pulse definitions, damping values, contact stiffness — producing results that are difficult to compare or use for portfolio-level decisions.

Output that requires expert interpretation. Raw CAE results — stress contours, displacement fields, time histories — require specialist judgment to extract actionable conclusions. Without automated post-processing, the same resource bottleneck that limits access also limits utility.

Physical testing answers too late; traditional CAE demands too much. Neither approach, used independently, meets the need for early, accessible, and repeatable shock assessment.

	Physical Testing Alone The late-answer problem	Traditional CAE The expertise barrier	What's needed Early · Accessible · Repeatable
When results are available	✗ After design is frozen	✗ After weeks of model setup	✓ During design phase
Expertise required	✗ Test lab + scheduling	✗ Specialist CAE engineer	✓ Design engineer with guided workflow
Design insight provided	✗ Pass / fail only	△ Detailed but requires interpretation	✓ Actionable, automated outputs
Consistency across programs	△ Depends on test setup	✗ Varies by analyst	✓ Standardized templates
Cost to iterate	✗ High — prototype rebuild required	✗ High — manual re-setup per scenario	✓ Low — parametric batch runs

✓ Meets need △ Partial ✗ Gap

Figure 3. Physical testing and traditional CAE each address part of the reliability problem but leave complementary gaps: one provides answers too late in the development cycle; the other requires expertise and effort that limits its reach.

Keysight Multiphysics: A Guided Approach to Virtual Shock Analysis

Keysight Multiphysics addresses the barriers identified above through a template-based, wizard-driven workflow that encapsulates simulation best practices into reusable, standardized configurations. Users define geometry, constraints, test environment, and evaluation targets; the workflow automates mesh generation, material assignment, load definition, solver execution, and report generation.

The result is a shock and drop analysis capability accessible to design engineers without CAE specialization, producing consistent and decision-ready outputs from the first use.

Wizard-based UX with built-in guardrails. A step-by-step guided interface enforces input validation and best-practice defaults throughout model setup. Design engineers can execute shock and drop simulations with a short learning curve, without knowledge of solver configuration or contact formulation.

Embedded electronics-focused material library. A curated material database covers common enclosure materials, board substrates, structural components, and packaging materials. Default properties reduce setup effort and modeling errors for non-specialist users. Expert users can extend the library with custom material models, and the solution supports connection to third-party material databases including TOTAL MATERIA™.

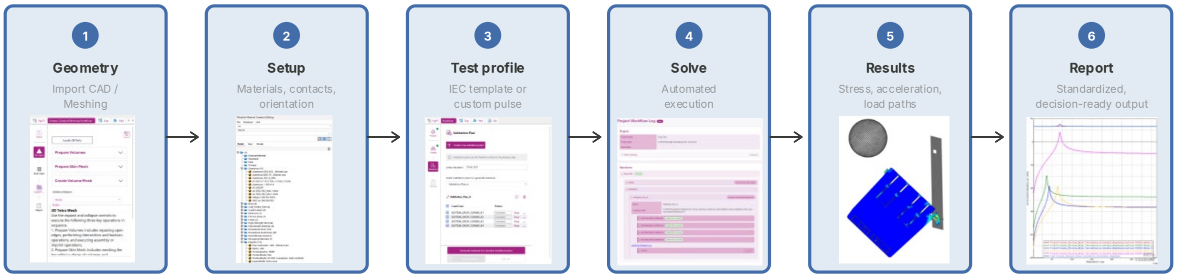
Centralized connections and contacts manager. Assembly interactions — contact pairs, interface definitions, joint conditions — are defined once and reused consistently across iterations, eliminating a major source of manual rework and inter-analysis inconsistency.

Simulation templates aligned to standard test profiles. Ready-made load case templates cover IEC 60068-2-27 (shock), IEC 60068-2-31 (drop and topple), and spherical impact configurations. Templates map directly to physical test definitions, enabling pre-test prediction and post-test correlation without manual translation of test conditions into simulation inputs.

Validation plan-driven execution. Predefined validation plans are executed in a single step, with automatic run generation, scenario selection, and result tracking. Multiple drop orientations, impact locations, or design variants are evaluated within a single workflow session.

Automated reporting and results visualization. Standardized report outputs are generated automatically for each test type, including acceleration-time histories, peak response metrics, pulse duration, and frequency content. Outputs are formatted for direct use in design reviews and qualification documentation, without post-processing by a specialist.

Batch runs and parametric studies. Systematic exploration of pulse severity, damping, support stiffness, and design variants is supported through automated batch execution and Design-of-Experiments (DoE) workflows, enabling efficient coverage of the test matrix.



Keysight Multiphysics — guided shock and drop analysis

Figure 4. From geometry input to standardized report: the Keysight Multiphysics guided workflow automates each stage of shock and drop analysis, reducing setup from days to hours for design engineers without CAE expertise.

Methodology: Shock and Drop Analysis Configurations

Keysight Multiphysics supports the system-level shock and drop load cases most encountered in electronics qualification programs. Three representative configurations are detailed in the following subsections; the load case library is extensible to accommodate in-house standards and custom industry requirements beyond those covered by default templates.

The analysis scope is system-level: the model captures the complete electronic system including enclosure, internal subassemblies, mass distribution, and — where applicable — packaging. This abstraction is appropriate for early-stage design evaluation and comparative studies, where consistency of assumptions and alignment with physical test intent matter more than component-level detail.

Tilt Drop / Edge Drop

Free-fall events where the system impacts a rigid surface on a face, edge, or corner. These tests evaluate global enclosure robustness and shock load transmission into internal electronics. Applicable standard: IEC 60068-2-31.

Model representation: system orientation and drop height, rigid impact surface, free-flight kinematics followed by transient contact. Face, edge, and corner orientations are handled within the same template by changing the drop angle parameter.

Ball Impact

Localized shock events caused by a spherical impactor striking the product surface. Used to assess enclosure integrity, display protection, and localized load transfer into subsystems.

Model representation: impactor mass, geometry, and velocity; localized contact region; support or backing compliance. The template covers both compliance-type and rigid backing configurations.

Packaged Drop

Free-fall drop of the complete packaged product — system plus protective packaging — onto a rigid surface. Evaluates how packaging attenuates impact energy and transfers residual load into the product. Applicable standard: IEC 60068-2-27 (equivalent shock pulse) combined with direct impact kinematics.

Packaging is represented through effective material properties and contact layers that reproduce dominant shock attenuation behavior, without explicit modeling of foam microstructure or corrugation geometry. This approach is consistent across programs and can be updated as packaging designs evolve.

Shock Loading Definition

Shock severity is defined either through direct impact kinematics (drop height, impactor mass and velocity) or through equivalent acceleration pulse inputs. Standard waveforms — half-sine and trapezoidal — are available as template inputs for specification-driven evaluation. Both approaches map directly to the corresponding physical test definition.

Model Inputs

Category	Typical Inputs
Geometry	System enclosure, internal subassembly layout, key structural features, major packages
Mounting / Support	Mounting points, screw locations, edge clamps, chassis contacts, packaging interfaces, drop orientation
Materials	Enclosure and structural properties, board and subassembly stiffness/mass, packaging cushion properties
Shock environment	Pulse definition (peak acceleration, duration, waveform) or impact definition (drop height, velocity, impactor geometry)
Evaluation targets	Critical subsystems, heavy components, connectors, enclosure features, identified risk interfaces

Acceptance Criteria

System-level results are evaluated against three criteria consistent with standard qualification requirements:

- **Criterion 1:** Product is damage-free and functions to specification
- **Criterion 2:** Packaging maintains product position throughout the event
- **Criterion 3:** Cosmetic surfaces show no degradation

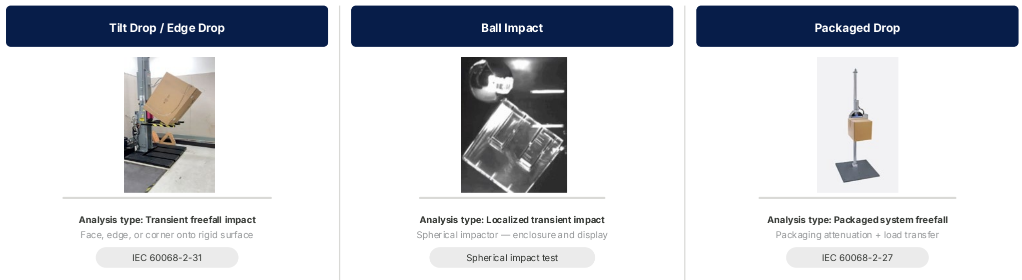


Figure 5. The three common test configurations — tilt/edge drop, ball impact, and packaged drop — cover the primary system-level shock qualification, each implemented as a standardized template within Keysight Multiphysics.

Business Impact

The primary value of early virtual shock analysis is the reduction of late-stage corrective action cycles by resolving design risks before hardware is committed. Physical qualification testing remains the authoritative final step; guided virtual analysis determines which design decisions are worth committing to before that step.

Reduction in Physical Test Iterations

A single physical shock test iteration — prototype fabrication, fixture preparation, lab scheduling, test execution, teardown, and engineering review — requires multiple working days and direct costs that scale with prototype complexity and lab access. In programs with multiple drop orientations, packaging variants, or design alternatives under evaluation, the total physical test matrix drives substantial iteration cost.

Guided virtual analysis reduces the number of physical iterations required by enabling virtual screening before hardware is built. Design variants are evaluated without material cost, in any orientation, before any prototype is committed. Physical test resources are directed toward the configurations that virtual analysis identifies as most critical.

Schedule Acceleration

Physical shock testing introduces delays from prototype build lead time, lab availability, and sequential test execution. These delays defer design decisions and increase program schedule risk.

Virtual shock analysis allows multiple drop orientations and impact scenarios to be evaluated before hardware is built, and design alternatives to be compared without rebuild cycles. Shock-sensitive subsystems can be identified before design freeze, when corrective action is least disruptive to the program.

Avoidance of Late-Stage Defects

Failures discovered at physical qualification, after design is largely frozen, require root cause investigation, design adjustment, prototype rebuild, and re-test. The cost and schedule impact of this corrective action cycle is substantially higher than the same failure identified during the design phase, where geometry, material selection, and structural configuration remain flexible.

Guided virtual analysis surfaces high-risk load paths and interfaces earlier, allowing design changes to be evaluated and resolved before hardware commitment. This reduces the probability of encountering preventable failures at qualification.

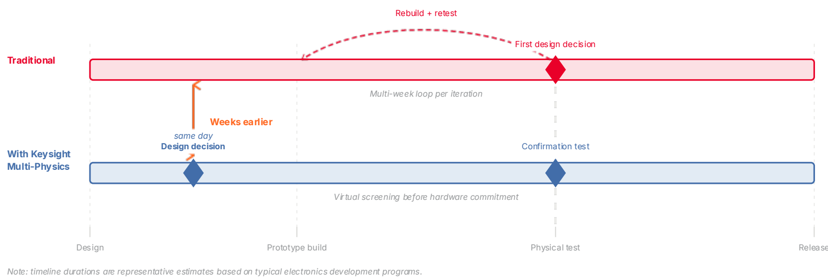


Figure 6. Introducing virtual shock analysis earlier in the development cycle compresses the time from design action to design decision, reducing the number of physical iterations required before qualification.

Case Study: Packaging Drop Optimization for a Tabletop Test Device

A high-fidelity tabletop test device required evaluation of its protective packaging design before committing to a physical prototype. The foam insert surrounding the device must attenuate impact energy across all drop orientations to two criteria: device accelerations must remain within an internally specified limit, and the device housing must not undergo plastic deformation during impact.

The analysis used the packaged drop validation plan template available in the standard delivery of Keysight Multiphysics. Rather than configuring each drop orientation as a separate model, the validation plan executes the full orientation matrix as a single run. The model captured the device, foam cushioning, and outer packaging shell as a complete assembly. For each orientation, device accelerations were extracted at defined monitoring locations, and the stress state of the housing was evaluated against the material yield limit. Figure 6 shows the edge drop configuration and the corresponding equivalent stress distribution on the device housing grate, rendered as a semi-transparent overlay on the physical assembly.

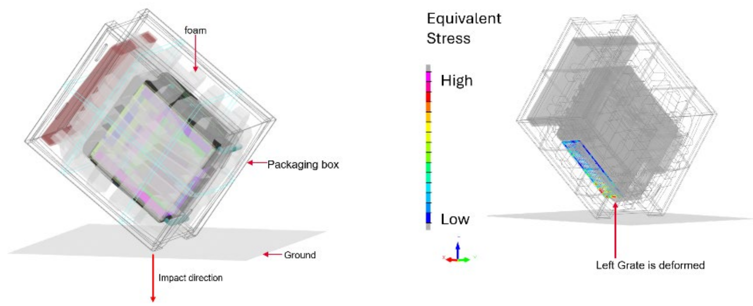


Figure 7. Edge drop scenario: physical test setup (left) and equivalent stress contour on the device housing grate from simulation (right, semi-transparent overlay). The stress distribution identifies the load path through the grate structure during impact.

With the full orientation matrix available from a single execution, foam design variants were evaluated iteratively. Each iteration produced peak accelerations, and housing stress results across all orientations simultaneously, allowing the design to be refined with complete visibility of the worst-case conditions. Foam geometry and material properties were adjusted until both acceptance criteria were satisfied across the full drop matrix. The optimized packaging configuration was established through virtual iteration before any physical prototype was built.

The simulation was subsequently validated against physical test results. Figure 7 compares the deformation of the housing grate between the physical test specimen and the simulation output. The deformation pattern and magnitude are consistent between the two. This agreement reflects not only the correct representation of the housing structure, but also the solver's ability to handle the full complexity of the assembly: the device in detail, the foam cushioning blocks with their nonlinear material behavior, and the cardboard outer packaging — all interacting as a coupled system across a range of material types in a single transient analysis.

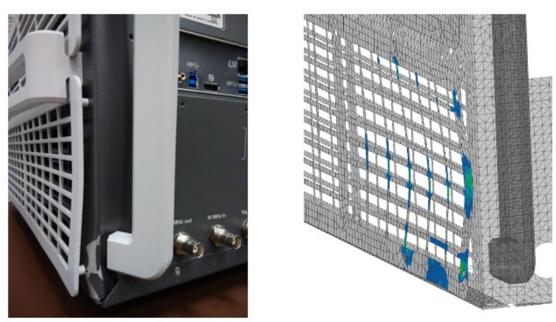


Figure 8. Housing grate deformation after edge drop: physical test result (left) vs. simulation prediction (right). Consistent deformation pattern and magnitude confirm the predictive capability of the model.

The case illustrates a broader principle: when the full test matrix is executed as a single validation plan and the simulation is grounded in physical test correlation, packaging optimization becomes a reliable design-phase activity — decisions are made before hardware commitment, and confidence is established before qualification testing begins.

Conclusion

Mechanical shock failures identified late in product development are among the most disruptive and costly events in an electronics program. Physical testing remains the authoritative qualification step — but its value as a design tool is limited by when it occurs. Guided virtual shock analysis addresses this by making system-level drop and impact evaluation accessible earlier in the development cycle, before hardware is committed and while design changes remain practical.

Keysight Multiphysics provides a structured path from geometry to decision-ready output, accessible to design engineers without CAE specialization. Standardized validation plan templates execute the full test orientation matrix as a single run, enabling systematic design evaluation and packaging optimization at the design phase. Physical test correlation on a representative packaged drop case confirms that the solver handles the material diversity and assembly complexity of real electronics packaging reliably.