WHITE PAPER

Getting Road Load Data Right

From Measurement to Confident Product Design Decisions.

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From Measurement to Confident Product Design Decisions

Road load data acquisition, or RLDA, provides the real-world evidence engineering teams need to design vehicles and components that are durable, reliable and fit for purpose.

By measuring the loads, strains, vibrations, temperatures and operating conditions experienced by a vehicle, engineers can better understand its actual usage environment. This information can then be used to validate design assumptions, support simulation, define laboratory tests and assess product durability.

However, collecting large quantities of data does not automatically create reliable engineering insight.

RLDA workflows are often fragmented across sensors, data acquisition hardware, vehicle networks, analysis tools and engineering teams. When these elements are treated as separate activities, important information can be lost, data quality problems may go undetected and engineers may spend significant time preparing data before it can be used.

A robust RLDA program therefore needs to treat the full measurement chain as one connected engineering workflow—from test definition and instrumentation through to data validation, analysis and reuse. HBK brings together sensors, rugged data acquisition, measurement software, engineering analysis and data management to support the complete RLDA workflow—from the first measurement through to long-term data reuse.

Why road load data matters

Every vehicle, component or subsystem must meet defined engineering requirements.

A structural component may need to remain free from cracks after a specified mileage. An off-highway vehicle may need to operate for thousands of hours. A suspension component may need to withstand repeated loading while meeting strict performance and weight targets.

To design against these requirements, engineering teams must understand the conditions the product will encounter in service.

Early in development, these conditions may be represented by assumptions, historical data or simulated loads. RLDA provides an opportunity to verify those assumptions using measurements from real operating environments.

Reliable road load data can be used to:

- Understand and validate product performance
- Verify and update design assumptions
- Provide realistic inputs for simulation
- Define representative laboratory tests
- Correlate physical and virtual simulation results
- Support durability and reliability assessments

RLDA is therefore much more than a data-collection exercise: it connects real-world product usage with design, simulation and validation.

Connecting physical and virtual development

Computer-aided engineering (CAE) tools allow teams to virtually evaluate designs before physical prototypes are available. This can reduce the number of development iterations, identify potential weaknesses and help teams explore more design options.

However, CAE simulations still require representative input data and evidence that their predictions reflect reality.

Physical testing and virtual testing should therefore be considered complementary. Simulation predicts how a design may behave, while RLDA measures how the vehicle and its environment actually behave.

Measured road loads can be used to supply realistic inputs, compare predicted and measured responses and refine simulation models. This helps engineering teams establish where virtual methods can be trusted and where further physical validation is required.

Creating a complete road load dataset

A traditional RLDA program may focus on measurements such as strain, acceleration, force, displacement and temperature. These signals quantify the physical response of the vehicle or component, but they do not always explain why an event occurred.

A more complete dataset combines structural measurements with information about the vehicle's operating state and environment.

Depending on the engineering objective, a test may include:

- Strain gauges
- Accelerometers
- Load and force transducers
- Torque sensors
- Displacement sensors
- Pressure sensors
- Temperature sensors

HBK's measurement portfolio includes sensors and transducers for capturing structural and dynamic behaviour, while MicroStrain inertial measurement units can provide synchronised pitch, roll, yaw and vehicle orientation data.

Additional channels can provide the context needed to interpret the measurements. CAN bus measurements add information such as vehicle speed, engine or motor speed, gear selection, throttle position and more. GPS can connect a load event to a specific point on a proving ground, road, field or work site. Video can reveal surface conditions, obstacles or driver behavior that may not be visible in sensor data.

Synchronising these sources creates a more useful engineering dataset. Instead of showing only that a high load occurred, the data can reveal where it happened, what the vehicle was doing and which operating conditions contributed to it.

Preserving traceability from the start

The long-term value of road load data depends on the information preserved with it.

Months or years after a test, another engineer may need to understand important metadata like:

- Which vehicle configuration was tested
- Who completed the test
- Which procedure was followed
- Which sensors were used
- Where it was installed
- What calibration was applied
- Which acquisition hardware and software were used
- Whether any unusual conditions occurred

These metadata need to be stored with the data files. When this metadata is stored separately or relies on individual memory, confidence in the dataset decreases over time.

HBK's catman software supports measurement configuration and traceability at the point of acquisition. Sensor databases can be used to assign calibration information, serial numbers and measurement settings to individual channels. Test parameters such as the operator, project, vehicle configuration and test location can also be stored with the resulting dataset.

Embedding this information in the data creates a traceable record that follows the measurement throughout the workflow. The principle is simple: whenever an engineer takes time to understand or resolve something during testing, that knowledge should be documented with the data.

Using zero values as an early warning

Pre-run zero values can provide useful information about the condition of strain gauges and instrumented components.

A significant change between test runs could indicate:

- A strain gauge beginning to fail or lift
- A damaged sensor or cable
- Permanent deformation in the component
- The beginning of a structural crack
- An unexpected change in the test setup

Monitoring these values can help teams identify problems before further testing is completed and reduce the risk of unusable data affecting the remainder of the program.

Acquiring data reliably in demanding environments

Vehicle testing exposes data acquisition equipment to harsh conditions that differ significantly from those in a controlled laboratory.

Systems may experience shock, vibration, temperature changes, humidity, contamination, power interruptions and limited installation space. Tests may also take place without a computer continuously connected to the equipment.

Fusion Rx is HBK's rugged, centralised data acquisition system for mobile and in-vehicle testing. It is designed to collect synchronised analogue and digital measurements under demanding environmental conditions while storing data locally for autonomous operation.

Fusion Rx can be configured before the test and then operated without a permanently connected PC.

Once testing is complete, the recorded dataset can move directly into the validation and analysis workflow.

Synchronised measurement

A modern RLDA program may include hundreds of analogue and digital channels. These channels are most useful when they share a common time reference.

Synchronisation allows engineers to compare a strain or acceleration event with vehicle speed, driver input, GPS position and video at exactly the same moment.

For larger tests, multiple acquisition systems may need to be combined. Accurate timing between systems ensures that the resulting measurements can still be treated as one coherent dataset.

Local data storage

Saving data locally on the acquisition hardware allows testing to continue without a permanently connected computer.

This is particularly valuable for mobile and unattended applications. It can also reduce the risk of losing a complete dataset if communication is interrupted or the system unexpectedly loses power. A reliable acquisition architecture preserves as much recorded data as possible, even when a test does not end as planned.

Validating data before it is used

Once measurement is complete, the next question is not immediately, "What does the data tell us?"

It is first:

Can this data be trusted?

RLDA requires significant time, people and equipment. Discovering a problem after the vehicle has been de-instrumented or the test team has left the proving ground makes retesting extremely expensive.

Data validation should therefore be treated as a formal stage of the workflow.

Engineers should assess whether:

- Sensors responded as expected
- Channels remained connected and operational
- Measurements fall within physically realistic ranges
- Repeated events produced consistent responses
- The test procedure was followed correctly
- The recorded event is complete
- The dataset is suitable for its intended analysis

nCode GlyphWorks provides a graphical, process-based environment for reviewing and validating large quantities of road load data.

Repeatable workflows can be created to screen hundreds of channels and test runs using statistical summaries, signal-quality checks and visual comparisons.

Screening large datasets

A test may contain hundreds of channels and dozens of runs. Reviewing every waveform manually is rarely practical.

Automated statistical summaries can calculate maximum, minimum, mean and root mean square values for each channel and event. This makes it easier to identify:

- Channels that remained at zero
- Values outside expected ranges
- Differences between left- and right-side measurements
- Inconsistent repeated runs
- Potential sensor saturation
- Unexpected changes in signal behavior

Instead of manually reviewing every waveform, engineers can focus their attention on the channels and events most likely to require investigation.

Identifying data anomalies

Isolated spikes may result from electrical noise, temporary connection problems or sensor errors rather than a genuine structural response.

A transient strain or acceleration event will normally exhibit a physically credible dynamic response. A single, extreme value with no corresponding behaviour around it may therefore require investigation.

nCode GlyphWorks workflows can flag these events and, where appropriate, support controlled signal processing for correction. The original measurement, processed result and method used should remain traceable.

Validation also helps determine whether testing is complete. Before instrumentation is removed, the team are then confident that all required events have been captured and that critical channels are usable.

Turning measurements into engineering decisions

Raw road load data is usually stored as time series information containing millions of measured values. These waveforms are necessary, but they are not the final engineering answer.

The goal of analysis is to convert the data into conclusions such as:

- What was the maximum load or strain?
- Which event was most severe?
- Does the component remain below its yield stress?
- Which operating condition creates the most fatigue damage?
- How many duty-cycle repeats can the component withstand?
- Where is structural failure most likely to occur?

Once data has been validated, nCode GlyphWorks can apply repeatable fatigue, durability and vibration analyses.

Understanding events in context

Combining measurements with GPS and video allows engineers to investigate specific moments more efficiently.

A test route can be color-coded using speed, strain, acceleration or another measured quantity. Engineers can then identify where the highest loads occurred and review the corresponding vehicle conditions.

Geofencing can isolate data from a particular section of a route, such as a pothole, rough-road section, twist ditch or high-speed corner. This allows relevant events to be extracted consistently without manually searching through an entire recording.

Fatigue analysis

Measured strain data can be used to estimate accumulated fatigue damage and predict life in terms of test repeats, mileage or operating hours.

Road load data can also be combined with finite element analysis (FEA). FEA describes how an applied load produces stress throughout a component, and is fed by road load data describing those varying load conditions.

Bringing the FEA and RLDA together makes it possible to estimate stress histories and fatigue life across the full component. This can identify locations that may remain below static strength limits but are still vulnerable to repeated cyclic loading.

Defining laboratory tests

Validated road load data can also be converted into controlled laboratory test specifications, including:

- Time-domain drive signals
- Block-cycle durability tests
- Frequency-domain vibration specifications
- Accelerated fatigue tests
- Multi-axis test-rig inputs

The aim is not always to reproduce every moment of field operation. It is to preserve the loading characteristics and fatigue damage that are relevant to the engineering requirement, while accelerating the test.

Managing road load data for future reuse

The volume of RLDA data can grow rapidly across vehicles, configurations, test events and product program. Without a structured management approach, valuable measurements may become difficult to find, understand or reuse. Teams may depend on individual test engineers to locate files or repeat testing because they do not know that suitable data already exists.

Aqira provides a web-based environment for managing and accessing engineering data across teams and locations. Road load datasets are catalogued together with their metadata, allowing engineers to search using parameters such as:

- Vehicle or product program
- Test location
- Vehicle configuration
- Powertrain
- Sensor or channel type
- Operating condition
- Test event
- Date or engineering team

Rather than relying on the original test engineer to find data, users can search for and access the measurements relevant to their work.

This supports greater reuse across physical testing, simulation and product-development teams while reducing duplicated testing and preserving engineering knowledge. This is particularly important for consumers of road load data – teams like CAE and test that rely on road load data as inputs to their critical workloads.

A connected RLDA workflow

A robust RLDA program brings the following activities together:

1. **Define the engineering objective**
   Establish the requirement or decision the data must support.
2. **Create the test procedure**
   Define instrumentation, operating events, vehicle configurations and acceptance criteria.
3. **Configure the measurement chain**
   Select appropriate sensors and synchronise analogue and contextual channels.
4. **Preserve traceability**
   Record sensor, calibration, test and vehicle information with the data.
5. **Acquire reliable measurements**
   Use hardware suited to the environmental and operational demands of the test.
6. **Validate the dataset**
   Confirm that signals are physically credible, complete and suitable for further use.
7. **Analyse and apply the results**
   Convert measurements into performance, durability, fatigue and simulation insight.
8. **Manage and reuse the data**
   Make datasets searchable and accessible for future engineering programmes.

Conclusion

Getting road load data right requires more than recording signals.

It requires a connected process that begins with the engineering requirement and continues through test planning, instrumentation, acquisition, validation, analysis and long-term data management.

Each stage affects the reliability of the next. Poor traceability makes measurements difficult to reuse. Unsynchronised data makes events harder to understand. Undetected sensor errors can distort fatigue calculations. Unvalidated measurements can undermine simulation and laboratory testing.

By treating the full measurement chain as one integrated workflow, engineering teams can reduce retesting, improve physical and virtual correlation and make better durability decisions. By combining HBK sensors, Fusion Rx, nCode GlyphWorks and Aqira, engineering teams can create a connected RLDA workflow that improves data confidence, reduces retesting and supports stronger physical and virtual correlation.

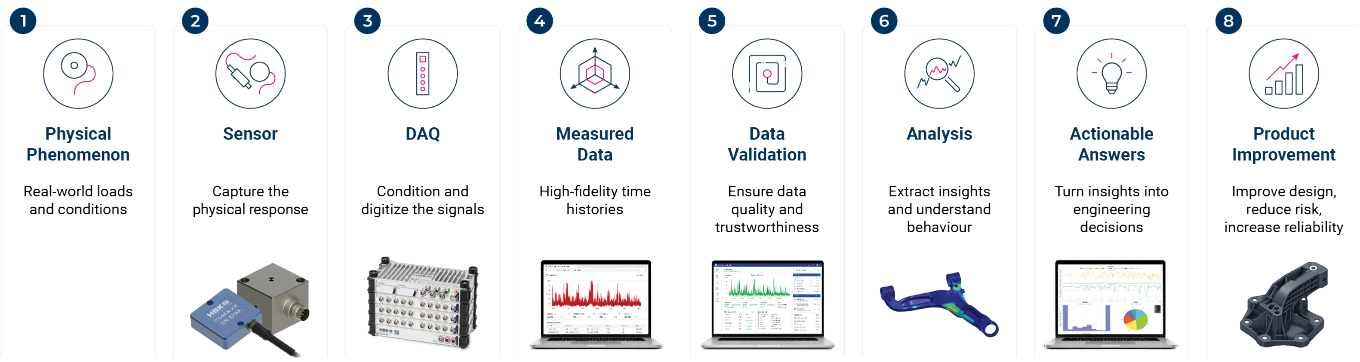
The result is not simply more data. It is trustworthy road load data that can be converted into confident product design decisions.

About HBK

HBK provides sensors, rugged data acquisition systems, engineering analysis software and data-management solutions across the road load data workflow.

By connecting measurement, validation, analysis and data reuse, HBK helps engineering teams turn real-world vehicle loads into reliable engineering insight.

Click here to read more: *Road Load Data Acquisition (RLDA) Solutions*



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