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NVH Testing of Automotive Powertrain Assemblies

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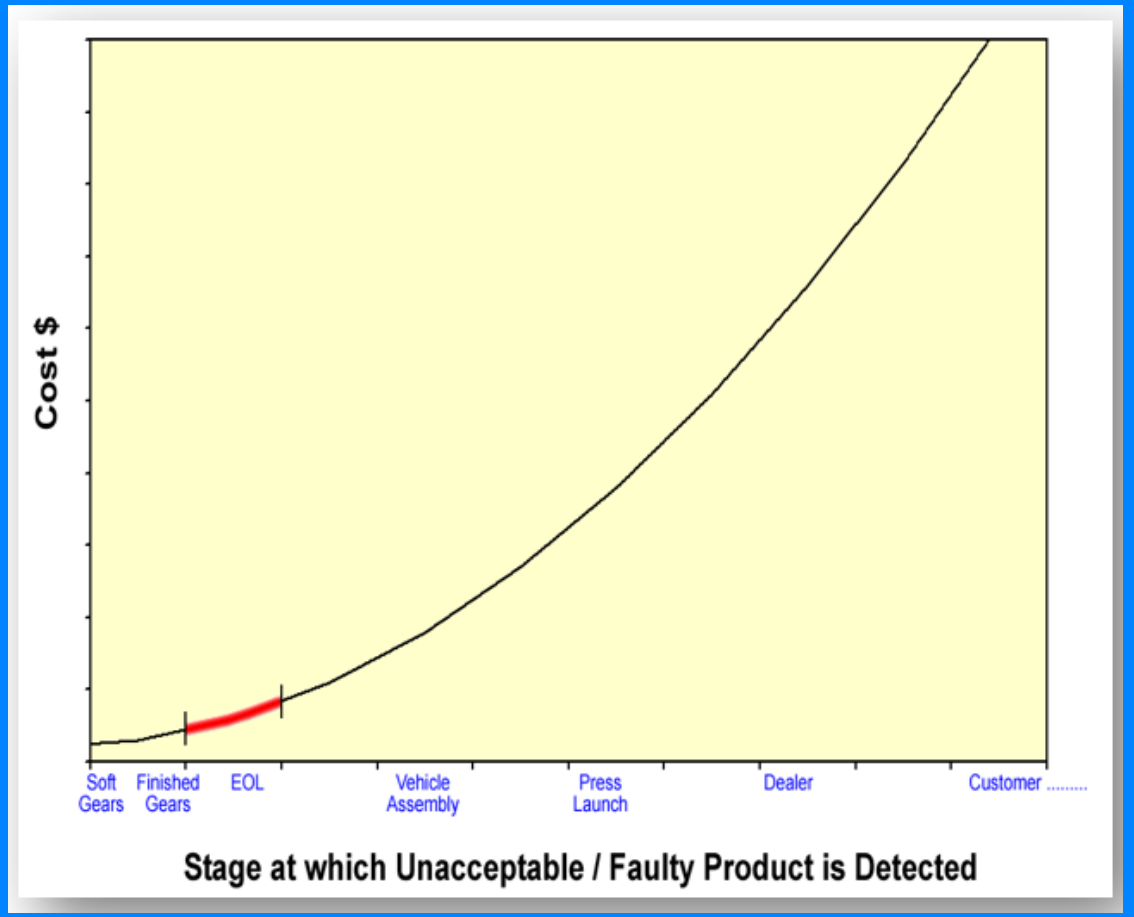
Expectations and Costs of Defects

- Driver/passenger expectations for **quieter** vehicles continue to increase.
- Vehicle build quality is increasing and cabin noise levels are **reducing**.
- Powertrain/power-steering noise/vibration becomes **increasingly** exposed.
- The move to electrified powertrains brings new challenges (even lower cabin noise levels and new types of noise that can annoy).
- Vehicles are increasingly being judged by their perceived level of noise/vibration “NVH refinement”.
- Warranty returns are very costly to the manufacturer.
- Testing in the factory costs money, but…
- The overall cost to an organisation can be reduced if a suitable and properly configured NVH screening test is in place.



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Payback

- An **effective** system can have a payback period of **<u>less than one year.</u>**
- An **ineffective** system can cost money throughout its life by:
  - Producing incorrect results.
  - Incorrectly sorting the good product from bad product.
- An NVH test system is only worth having, whatever its cost, if it can:
  - Detect good and bad product to the required degree of accuracy.
  - Diagnose reasons for failures.

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A Properly Implemented NVH Test System will...

• Detect **all** noise/vibration problems likely to annoy your customer.
• Detect assembly faults that might manifest themselves **after** customer use.
• **Guarantee** that all powertrain assemblies shipped are acceptable for noise/vibration.
• Provide a **fast** test, to avoid delays to production or **excessive** expenditure on multiple test machines.
• Provide **meaningful** and **cost-effective** test results.
• Generate **repeatable** results.
• Use **robust** and **reliable** equipment.
• Operate **automatically**.
• Have **flexibility** to deal with different product models - now and in the future.
• Be based on a history of **successful** operation elsewhere.
• Come with **expert** advice from the supplier.

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Noise & Vibration problems which affect customers

A. Periodic Noise/Vibration – A.K.A. “Whine”
   - Arising from imperfect gear profiles/mis-location of gears
B. ‘Knock’ and ‘click’ noises
C. Bearing Defects
D. Unexpected noises and/or vibrations
E. Rattling

	NVH Problem				
Analysis Technique	A	B	C	D	E
1 - Order Analysis	✓		✓	✓	
2 - Envelope Analysis		✓	✓	✓	
3 - Transmission Error	✓		✓		✓

All above analysis techniques require raw data whose sample rate is synchronized to the speed of the powertrain shafts.

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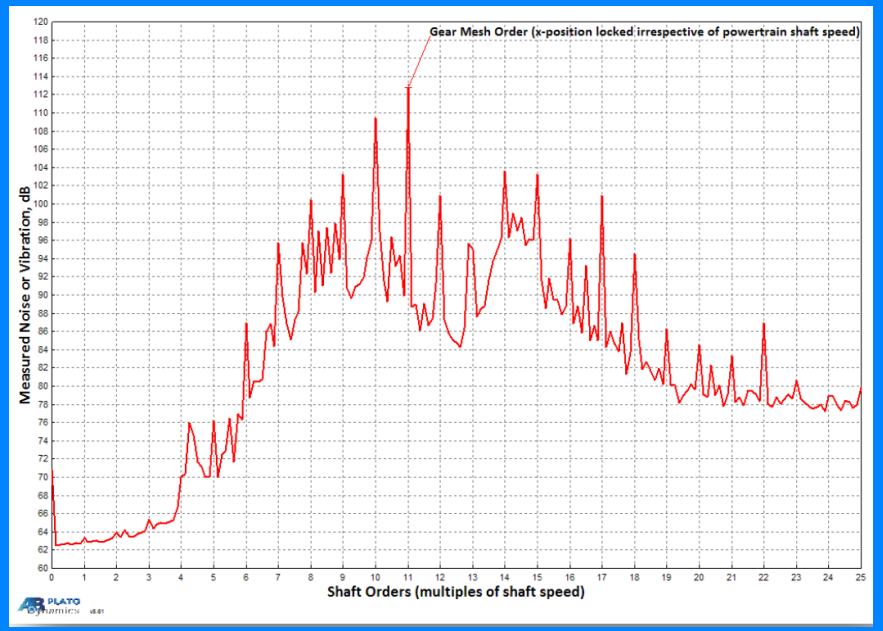
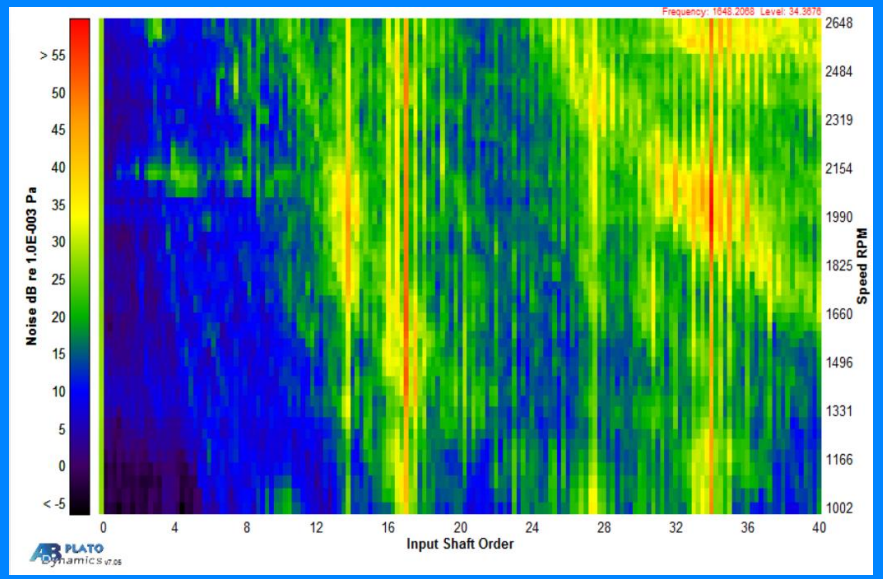
Analysis Technique 1 - High-Precision Order Analysis

- Standard frequency analysis can easily lose track if the powertrain changes its speed by very small amounts.
- Using a shaft speed signal to synchronise analysis to shaft rotation (**"order analysis"**) eliminates this source of error resulting in pin-point diagnostics.
- Order analysed speed sweep data is a very powerful aid to problem diagnosis.
- Production environment challenges:
  - Handle the vast amount of data produced from a relatively short duration test
  - Distil that data down into reports that allow manufacturing personnel to make meaningful decisions.





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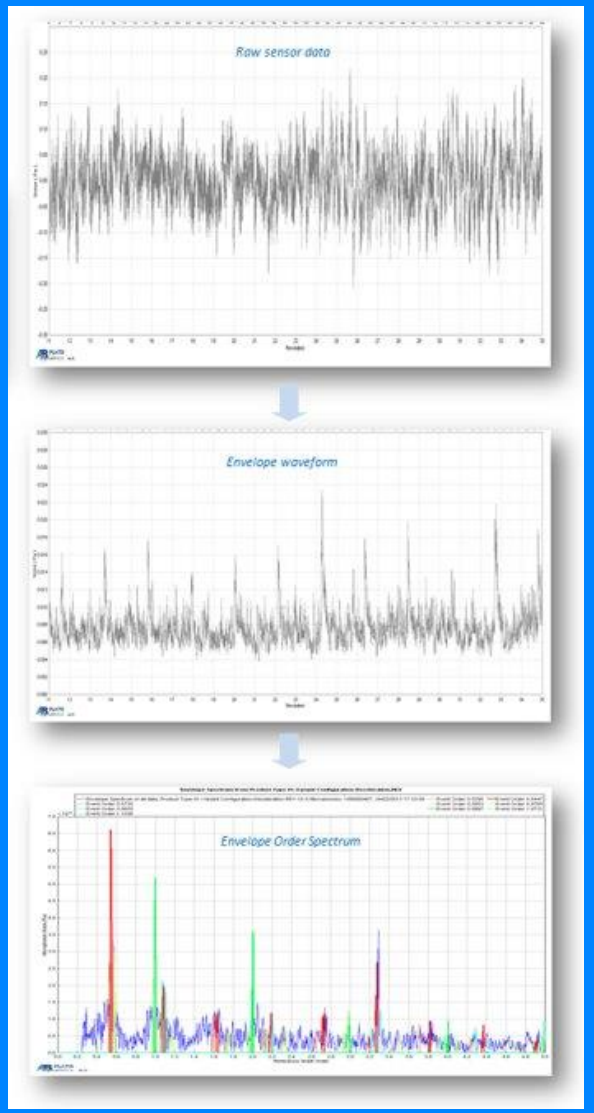
Analysis Technique 2 - Envelope Analysis

- Identifies defects at specific points on a rotating element, such as gear teeth and bearing defects.

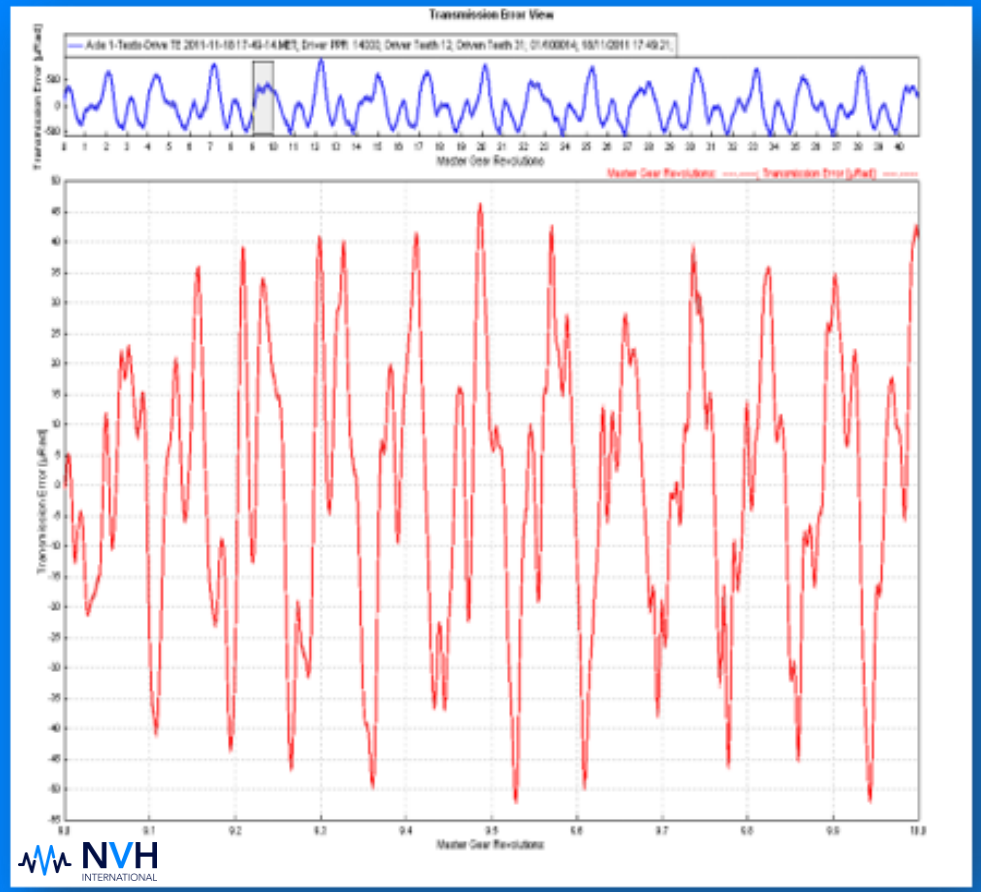
- Raw sampled data is converted into an envelope waveform that exposes repetitive events.

- Shaft speed synchronized raw data ensures that harmonic event series can be extracted as orders of shaft rotation; thereby facilitating accurate identification of defect source.



Analysis Technique 3 – Transmission Error

- Periodic automotive powertrain noise/vibration has a geometric source.
- In a perfect gear-mesh, the driving gear (when rotated at constant angular velocity) would transfer a different, yet perfect, angular velocity to the driven gear.
  - i.e. transmission error (TE) is zero.
- In practice, gear-meshes are not perfect:
  - Gear teeth and shafts bend under load
  - Gear contact patterns are affected.
- The error in the driven gear's angular displacement is called "**transmission error**" (measured in micro-Radians, or µ-metres at the gear pitch line).



This real TE example shows TE ranging up to ±50µRad (once "long wave" eccentricity has been removed from the results).

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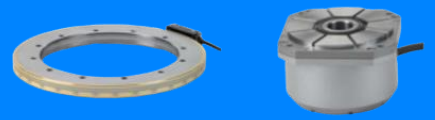
What & Where to Measure?

TE

- Precision angle encoders on input (driver) and output (driver) gear.

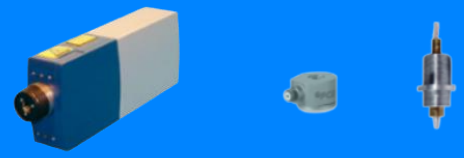


Torsional Vibration

- Torsional accelerometers, dynamic torque sensors within test machine driveline(s).

Linear Vibration

- Accelerometers/automated touch-probes (contacting), or laser vibrometers (non-contacting).



Radiated Noise

- Microphone array (in suitably low background and controlled environment).

- When specifying your NVH test system you should consider:
  - Where in the “NVH energy chain” you want to measure.
  - Whether more than one point in the chain makes sense.
- Different sensors are required for different measurements in the chain.
  - Choice of sensor impacts heavily on the design of the test machine and the test environment.

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Guarantee of Noise/Vibration Quality

- Millions of dollars have been spent on rejecting, returning, and reworking products that were deemed too noisy by the assembly plant, when the manufacturing plant has rated the products as ‘acceptable’.

- Many of these issues are associated with variability of the vehicles.
  - Essential to agree on end-of-line test pass/fail limits that define the noise of an acceptable product when used in otherwise acceptable vehicles.

- A powertrain NVH test system is only useful if:
  - It allows the manufacturer to guarantee to the vehicle assembly plant that the noise/vibration is acceptable.

- The NVH test system must be able to define limits, ideally based on:
  - feedback from in-vehicle noise test or
  - external (pass-by) noise tests if appropriate.

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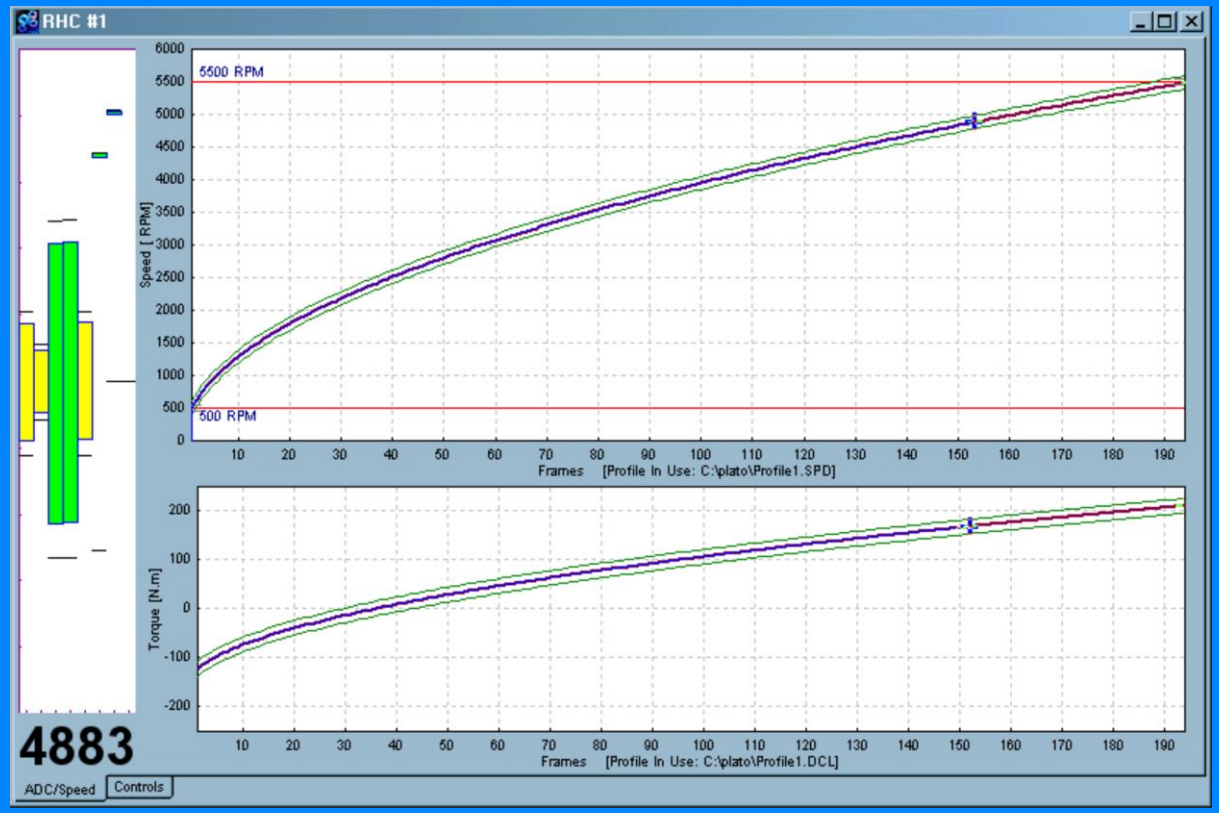
Fast and Meaningful Testing (Pt.1)

- Fast testing minimizes impact on manufacturing throughout, but there's no use if results are meaningless.

- Sufficient revolutions of the shafts (gears) within the product must be measured

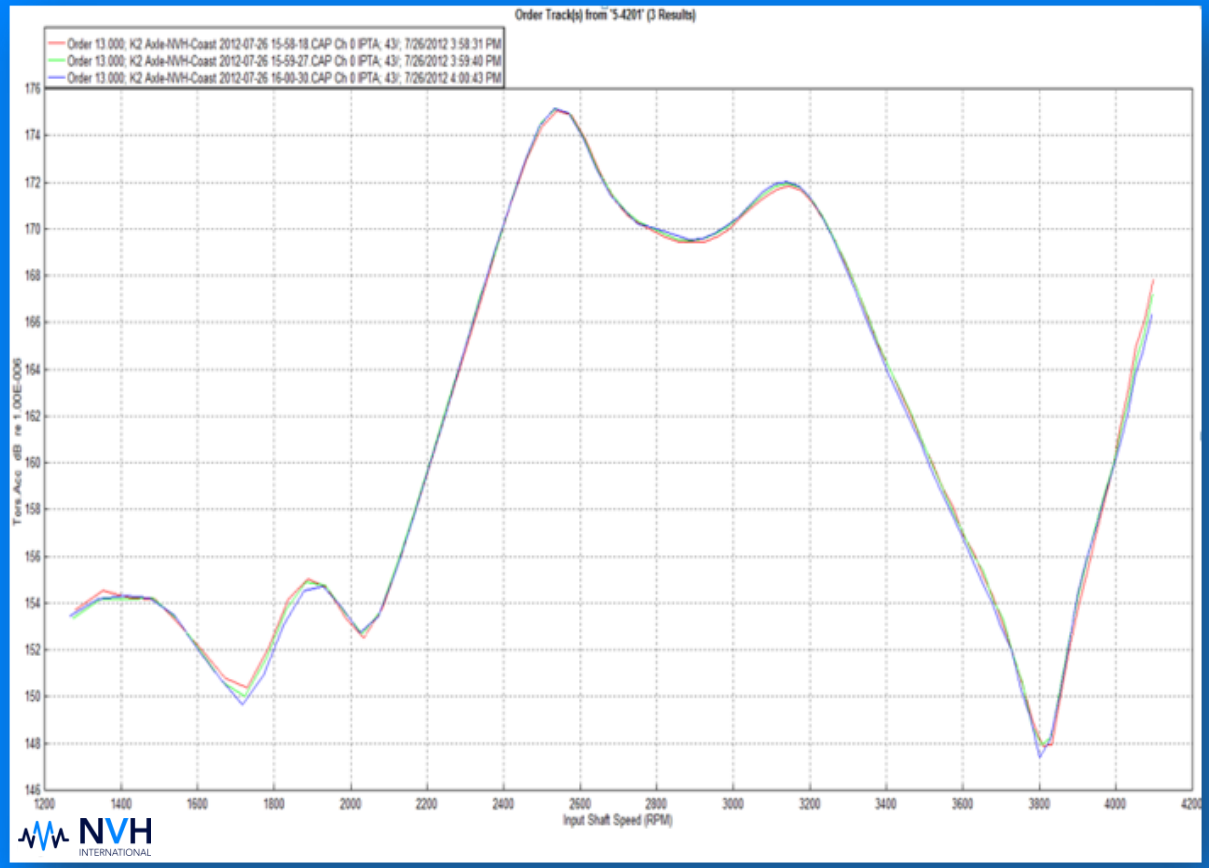
- Steady speed and torque tests can be fast, but they only provide "snapshots"
  - in service, the product will operate over wide ranges of speed and torque
  - customer complaints may arise at any combination of speed and torque
  - how will the steady speed and torque values be chosen?

- Meaningful and viable techniques involve:
  - **Speed sweeps** (with separate test stages for "drive" side and "coast" side loading).
  - **Torque sweeps** (typically at a shaft speed chosen to be in a "quiet" zone for the test system, with torque loading changing from "drive" to "coast").
  - A **combination** of the above.



Fast and Meaningful Testing (Pt.2)

- It may be tempting to use very high acceleration/ deceleration rates, but many customer complaints involve noise/vibration that occurs only over a small speed range.
- Very high acceleration/ deceleration rates can “gloss over” serious NVH issues.
- Speed sweep testing with NVH systems from NVHI regularly run sweeps up to 500rpm/s, sometimes 750rpm/s.
- Torque sweep testing with NVH systems from NVHI regularly run “full drive” load to “full coast” load in around 20s.



Typical order track repeatability from 350 rpm/s speed sweep.

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Reliable Equipment (Pt. 1)

- Reliability of computer systems (PCs) is not the main issue.
- Measurement electronics and computer systems from good suppliers are reliable for end of line test work.
- Electronics failures are rare if the system operates on clean electrical supplies
- PLATO currently supports a wide range of NI (National Instruments) data acquisition hardware.

Below, you can see popular **24-bit** analogue input devices that can all provide **power to IEPE-sensors** and have software controllable **AC/DC-coupling**.

					
Model	**NI-9234**	**NI-9250**	**USB-4432**	**PXIe-4492**	**PXIe-4497**
Channels	4, 8, 12, 16...	2, 4, 6, 8, 10...	5	8	16
Sample rate	51.2kS/s/chan	102.4kS/s/chan		204.8kS/s/chan	
Alias-free analysis range	20kHz	40kHz		80kHz	
= 100-order analysis to	6,000 rpm	12,000 rpm		24,000 rpm	
or, 200-order analysis to	3,000 rpm	6,000 rpm		12,000 rpm	
or, 400-order analysis to	1,500 rpm	3,000 rpm		6,000 rpm	

…and some popular chassis for the plug-in modules/cards:

PXIe-**1073** (5-slot) with MXIe-link to **PCIe-8361** in host PC

cDAQ-**9178** (USB)

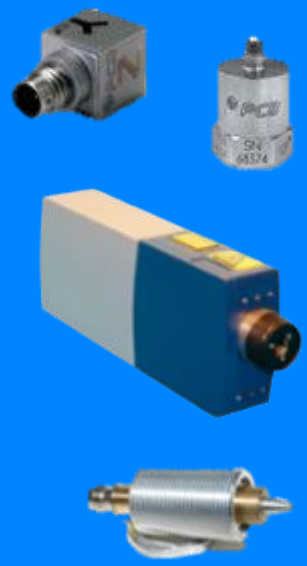
cDAQ-**9174** (USB)

Reliable Equipment (Pt. 2)

Linear Vibration

Reliability of transducers in the end-of-line test environment is paramount

- Manually installing accelerometers (using screw threads or glue). Uses up valuable cycle time and is often not practical.
- Fixed mounting of accelerometers on fixtures, or the test machine structure, introduces a transfer path that can be unduly influenced by product clamping, and the results are often physically too remote for meaningful product assessment.
- Non-contacting laser vibrometers have many advantages but they area relatively expensive option and care must be taken to ensure they are mounted in such a way as to isolate the measurement head from vibrations in the frequency range of interest.
- Spring-loaded(“touch-probe”) accelerometers are a good performance/robustness/price compromise.



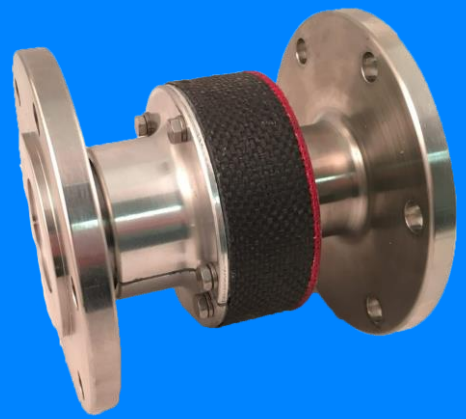
Reliable Equipment (Pt. 3)

Radiated Noise

- Systems based on arrays of microphones can have the microphones positioned 0.5 - 1.0m from the product under test.
- Out of the way of loading and unloading operations.
- Proved to be very reliable in production line environments.

Rotational Vibration

- Systems with torsional accelerometers or dynamic torque sensors embedded into machine drivelines are often the most robust solution



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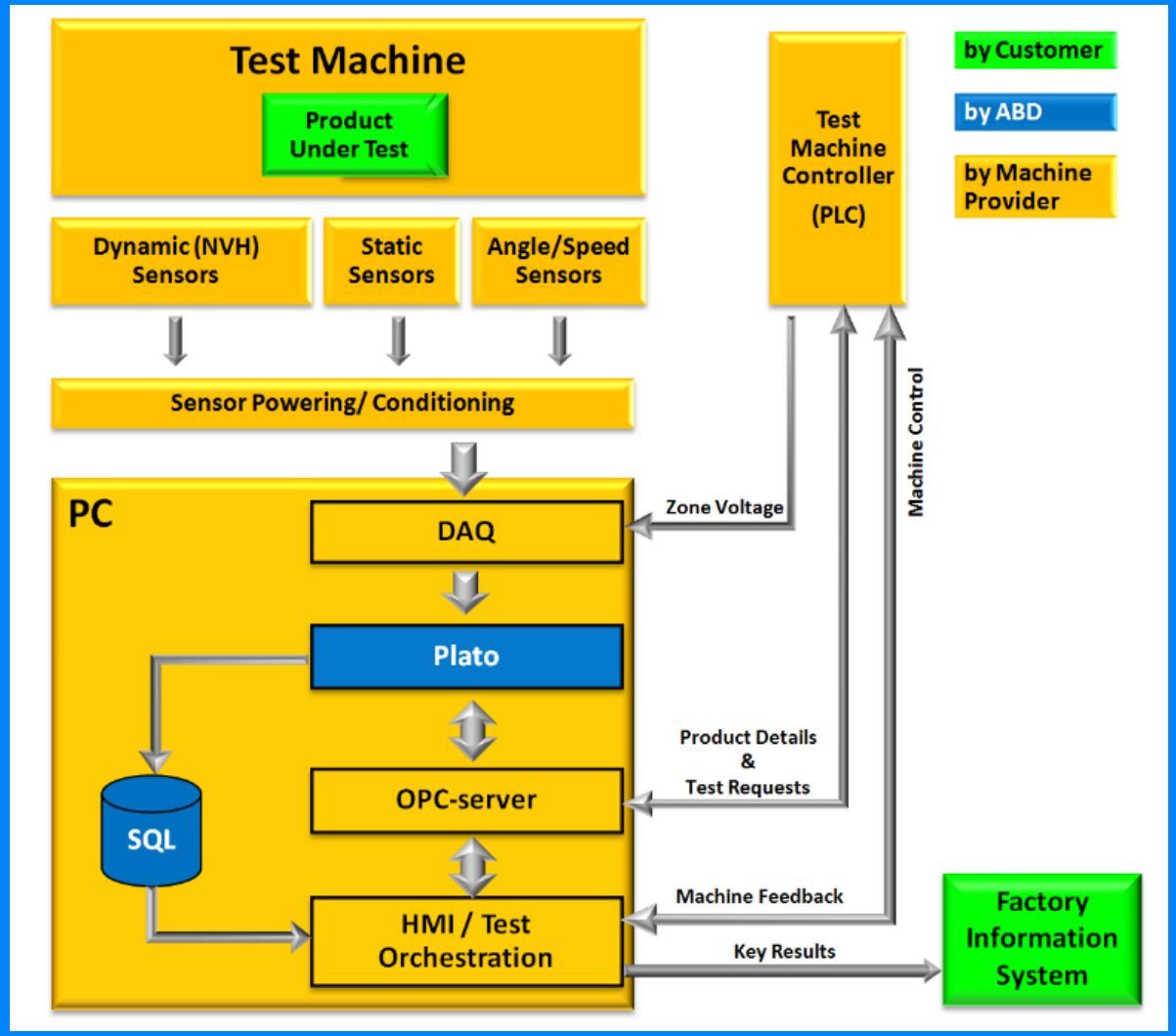
Typical (simplified) System Schematic



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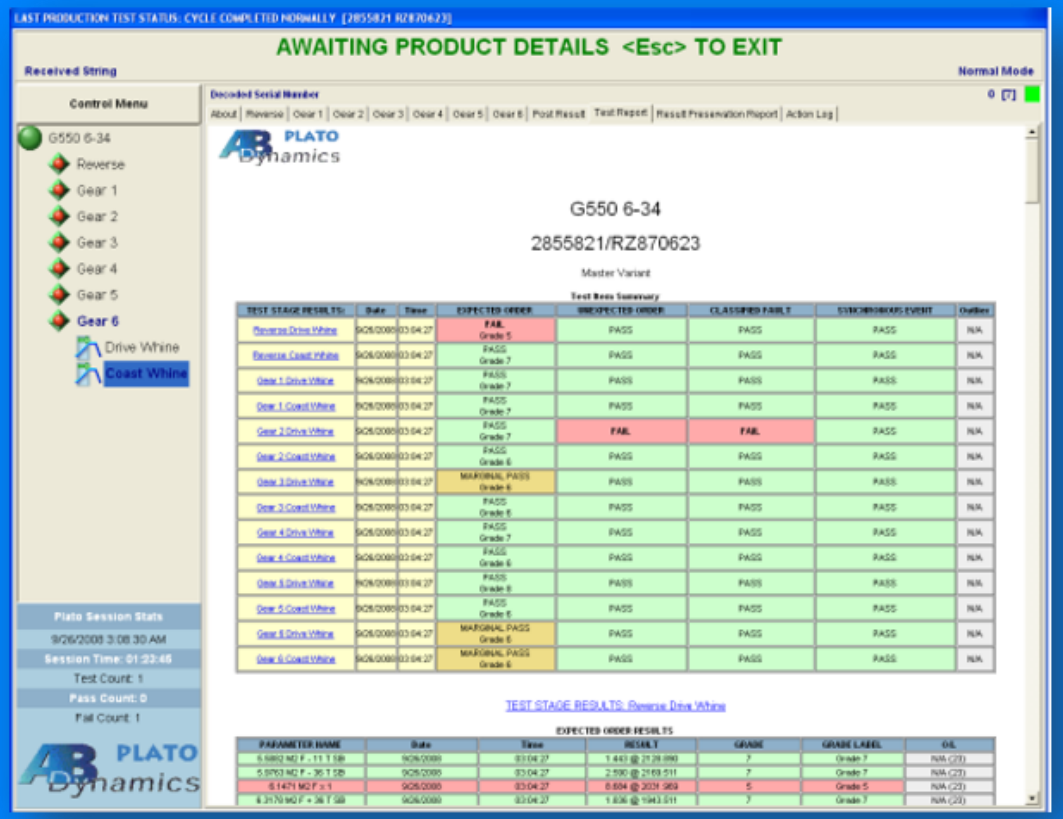
Automatic, Intuitive & Consistent Operation

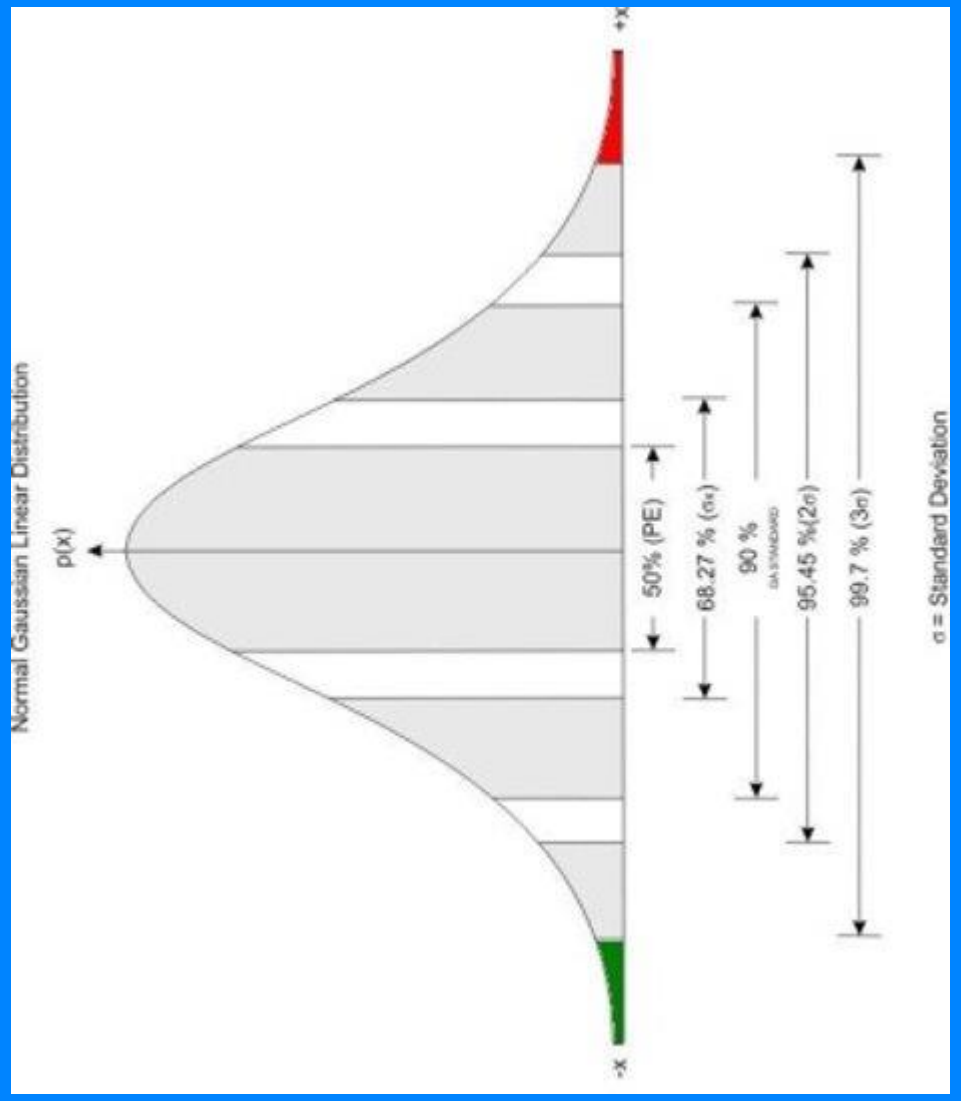
- It is not necessary to have an operator to listen to the noise of automotive powertrain assemblies in the factory.
- A measurement system can produce far more repeatable results, day after day, provided the correct measurement techniques are used.
- Good powertrain NVH test systems interact with test machine control systems and **produce results in a simple form for interpretation at the plant level.**
- **Pass/fail** and failure diagnostics must be provided by the system to assist rectification
- Test machine interaction includes automatic resetting of the measurement and analysis parameters if a different product is detected.
- Good systems self-check during each test to ensure:
  - sensors are operating satisfactorily
  - test schedule (speed and torque loading) has been followed correctly.



Clear presentation of results from complex analyses is paramount for take-up of NVH systems by manufacturing personnel.

NVH INTERNATIONAL

Accurate Pass/Fail Decision Making & Detection of Assembly Faults



Primary task: rate the quality of the powertrain for specific (**expected**) NVH features e.g., gear whine

- Expected NVH energy (the “shades of grey”) must be accurately assessed to determine pass/fail.
- The distribution of NVH energy for a production test process is likely to be Normal (Gaussian), with the majority of samples in the “middle ground”.
- Small movements in the pass/fail boundaries can therefore have major impacts on the viability of the manufacturing business

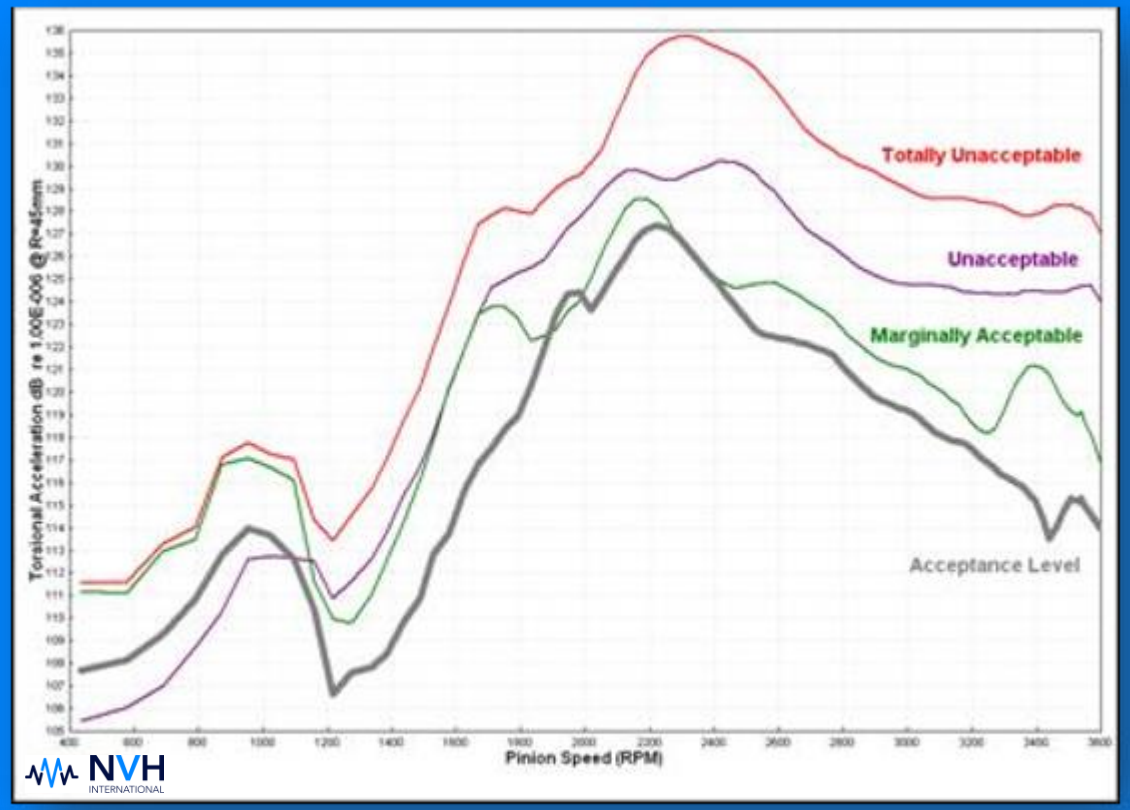
Secondary task: flag unexpected noises/vibrations.

- Systems that provide intelligent fault-classification and reporting of root-cause knowledge are to be preferred over those which simply report results in numerical form.
- Systems that automatically recognize and use abnormal data **prior to root-cause information** becoming available can dramatically transform the usefulness of the system to manufacturing personnel.

NVH INTERNATIONAL

Flexibility & Ability to Automatically Learn Reference (Acceptance) Levels

- Testing different products in any sequence requires the NVH test system to select the required test routine (speed and torque profiles etc.), reference levels and pass/fail limits.
- NVH signatures of automotive powertrain assemblies are complex datasets (thousands of points), so the pass/fail criteria must contain an equivalent amount of data.
- Systems that offer simple pass/fail criteria **rarely** produce meaningful results.
- Good NVH test systems automatically build reference levels by testing products that are known to be acceptable (or building average datasets from all samples tested).
- Automatic creation of reference levels (instead of manual definition) ensures that the characteristics of the product being tested on a specific test machine are encapsulated.
- Such encapsulation makes for easier transfer of pass/fail and grading of results to other test machines in a multi test machine scenario

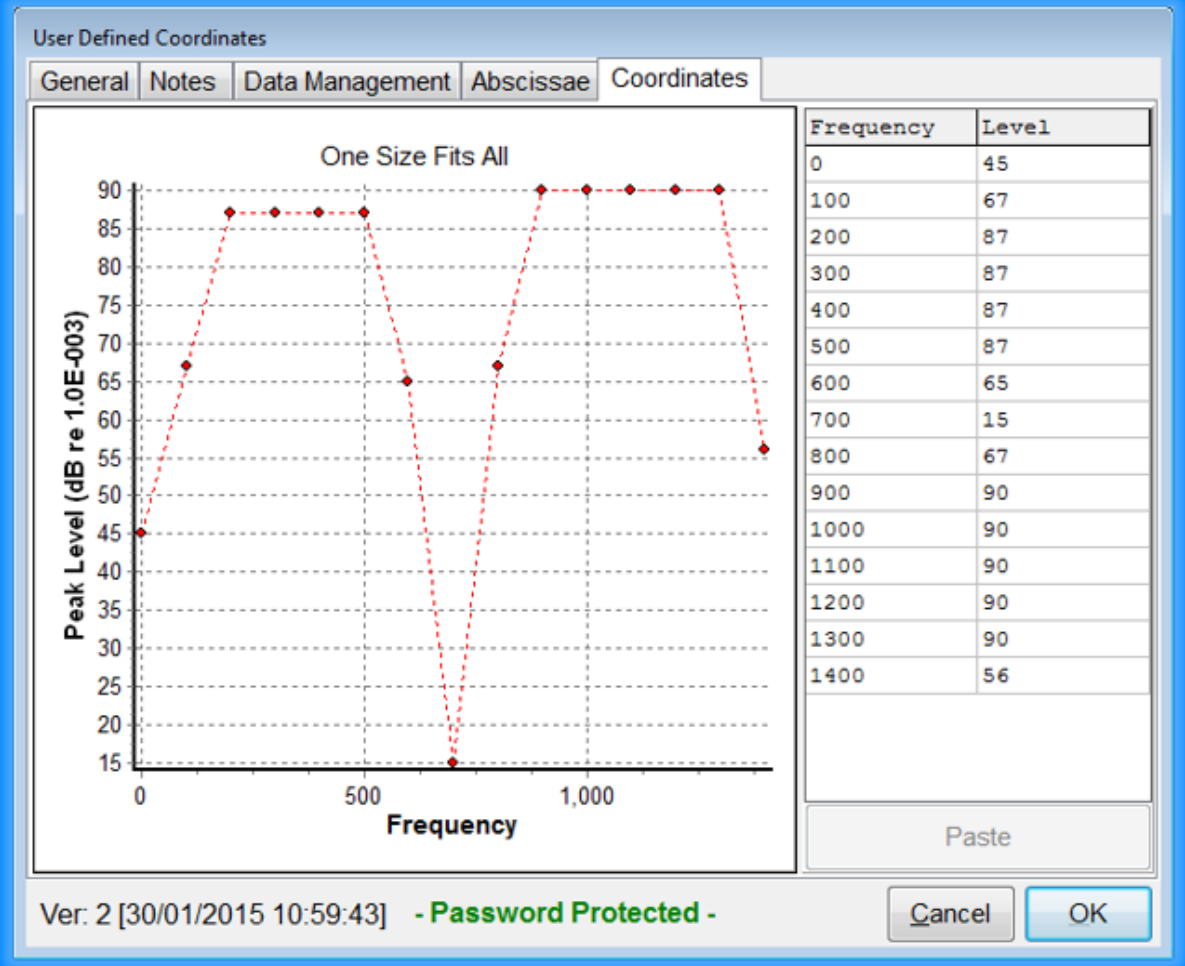


Complex response data (a function of the product under test and the test machine/conditions) demands equally complex acceptance limit criteria.

NVH INTERNATIONAL

Flexibility to Deploy User-Defined Reference (Acceptance) Levels

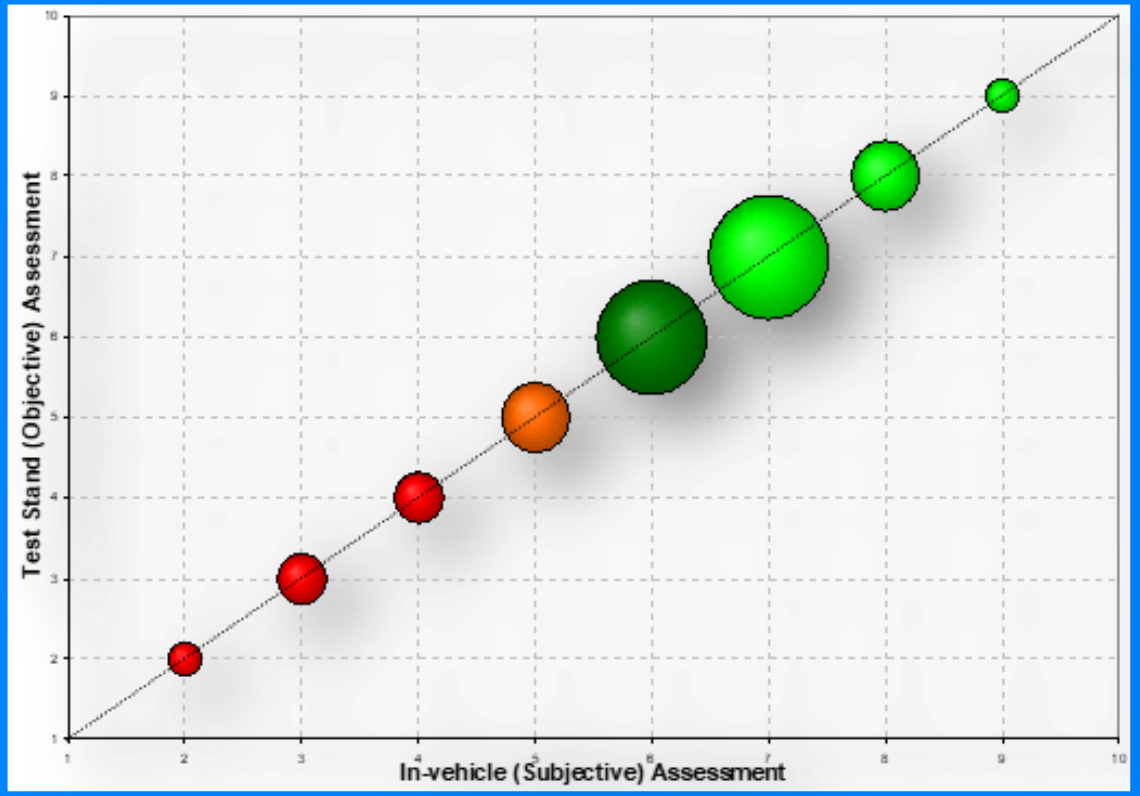
- Some customers prefer to define their own (absolute) limits (reference/ acceptance levels)
- PLATO's User-Defined Co-ordinates makes this an easy, intuitive and manageable process.



Manually created reference/acceptance limits –pasted-in from Excel™

Selection of a Supplier with a History of Successful Operation

- Many unsuccessful NVH test systems have been produced over the past 30 years.
- It is essential to investigate the success of existing users, and to establish at a technical level the reasons why a proposed system will work in your environment.
- Success must be judged by the ability of the NVH system to produce meaningful results i.e., results which:
  - Correlate strongly with in-vehicle (or exterior if appropriate) assessments of noise/vibration.
  - Pin-point manufacturing and/or assembly faults.



Target for gear-mesh whine: Perfect correlation between test machine NVH results and subjective assessments of gear whine noise in-vehicle.

NVH INTERNATIONAL

Availability of Expert Advice

- Manufacturing personnel cannot be expected to have the detailed knowledge required to get an NVH test system set up and working in a cost-effective manner.
- Can your supplier offer expert advice and assistance in the real world of production line testing.

Expert advice should include the following:

• **Assessment of the proposed installation** to ensure that the NVH test system and the test machine will be compatible. This may involve consideration of the mechanical and electrical design of the test machine.
• **Selection and installation of sensors** and relating signal conditioning.
• **Troubleshooting** during installation.
• **Training** and back-up material covering noise/vibration emission from automotive powertrain assemblies as well as operation of the NVH test system itself.
• Assistance with **interpretation of NVH results**, particularly while the customer is gaining initial experience of the system. This requires the supplier having knowledge of automotive powertrain design and gear manufacturing.

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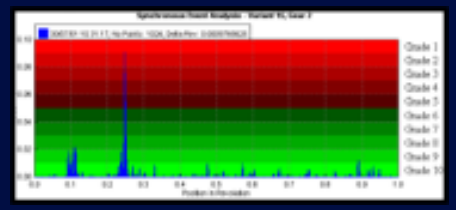
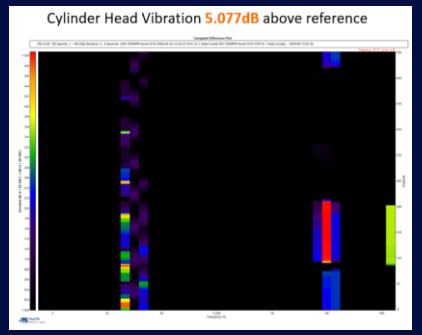
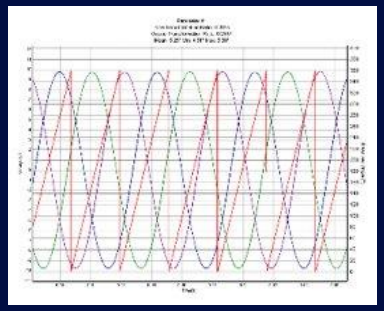
Software Options to Tailor Solutions (I)

PLATO is available as a core product (for expected and unexpected order analysis).

Add-on sub-products then provide more functionality.

Available Sub-Products:

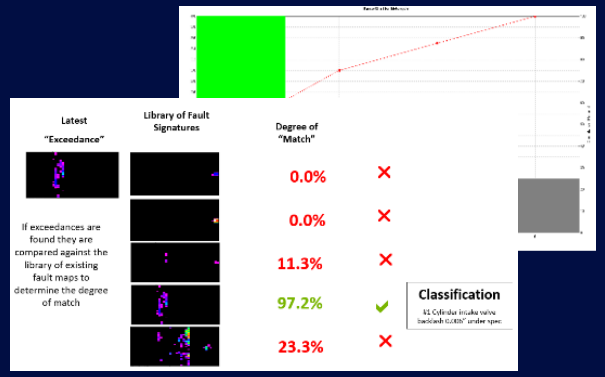
Revkit Objective bearing defects & gear face damage ("knock") analysis. Primarily used to detect increases in energy but also includes a minimum acceptance level strategy to identify faults that are witnessed by less noise/vibration e.g.missing parts.	 	***Dybal*** Dynamic & static balancing. Adds imbalance measurement &recommends position of correction (addition or subtraction of mass) for: - static (1-plane) imbalance. - dynamic (2-plane) imbalance.	
Nuren Adds super-fast 1/3-octave analysis for internal combustion engine work-cycle mapping, with automatic reference level building (per sensor) and comparison to establish abnormal signatures (maps).		***e-Kit*** Adds electric powertrain analyses (resolver offset & transformation ratio, eMotor back-EMF).	

Software Options to Tailor Solutions (II)

Available Sub-Products:

Focus

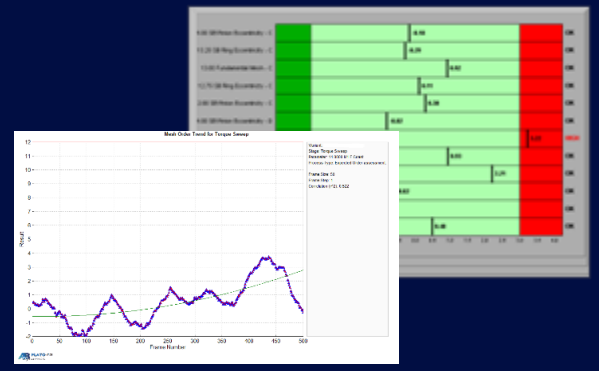
Works with NUREN to provide intelligent fault signature pattern matching/classification with automatic fault-library management. Keeps product knowledge with the test system and not in the heads of your personnel.



Stats

Adds statistical analyses of results on the test station PC.

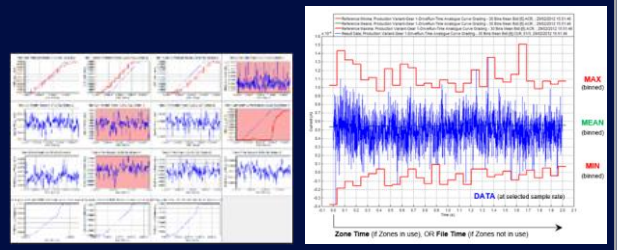
- Expected order trending
- Expected event trending
- Special disposition determination for BOBs and WOWs
- SPC



Timkit

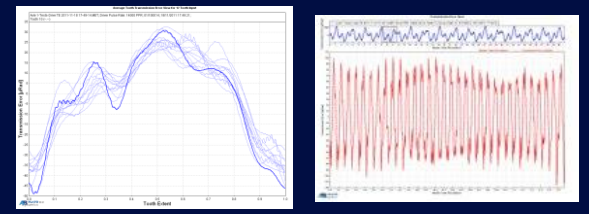
Adds time-history analysis for:

- ABS-sensor output verification
- Gear shift analysis



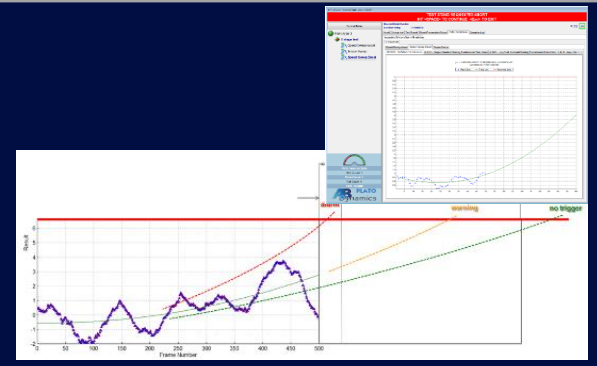
Metkit

Multi-channel event-timing for: Transmission error, backlash, PLRO & torsional vibration measurement.



Duramon

Condition (health) monitoring for fixed assets e.g. test machines. Detects adverse (increasing) trends in monitoring parameters. Warnings and/or alarms are displayed and indicated via OPC-tags so that other processes e.g. machine HMIs, can notify the user of the condition.



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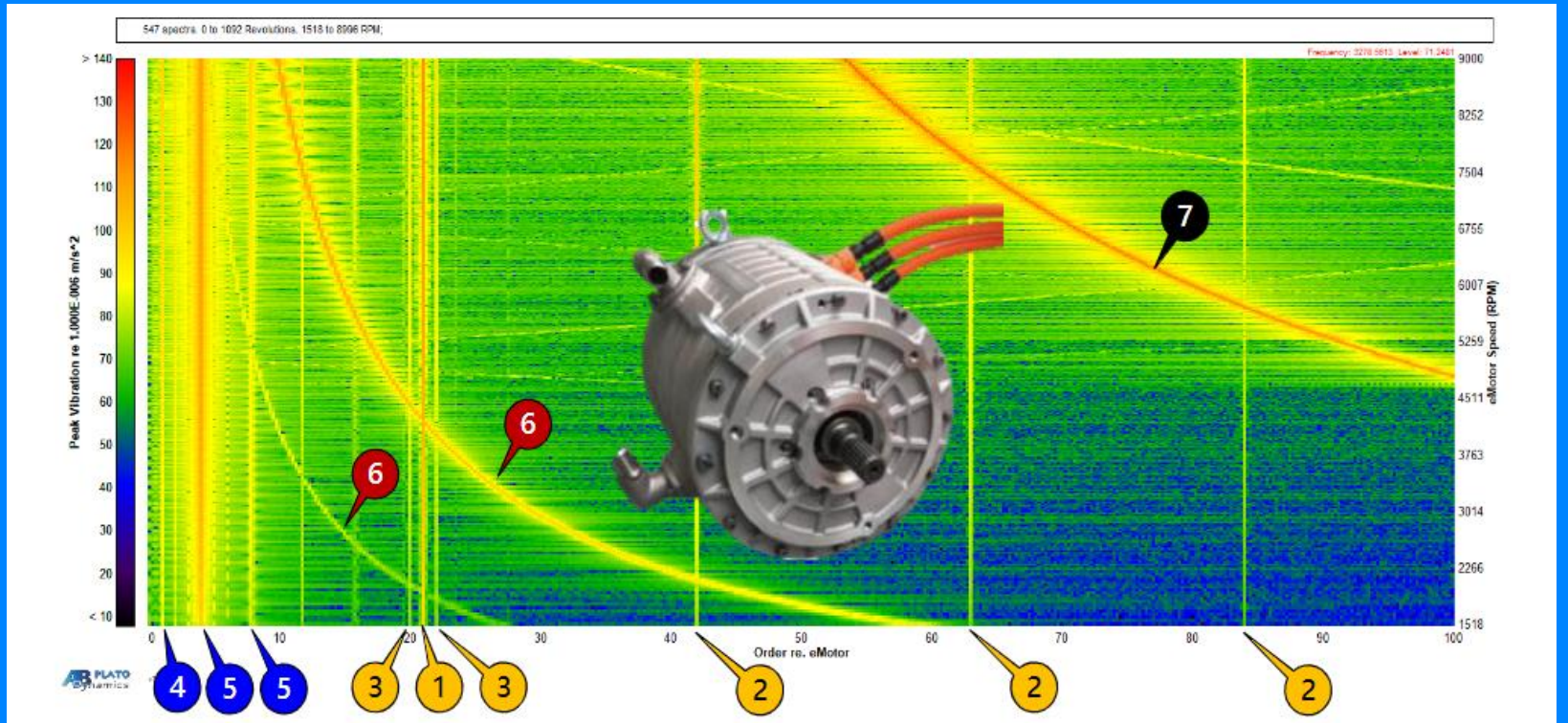
Electric/Hybrid (ePowertrain) NVH



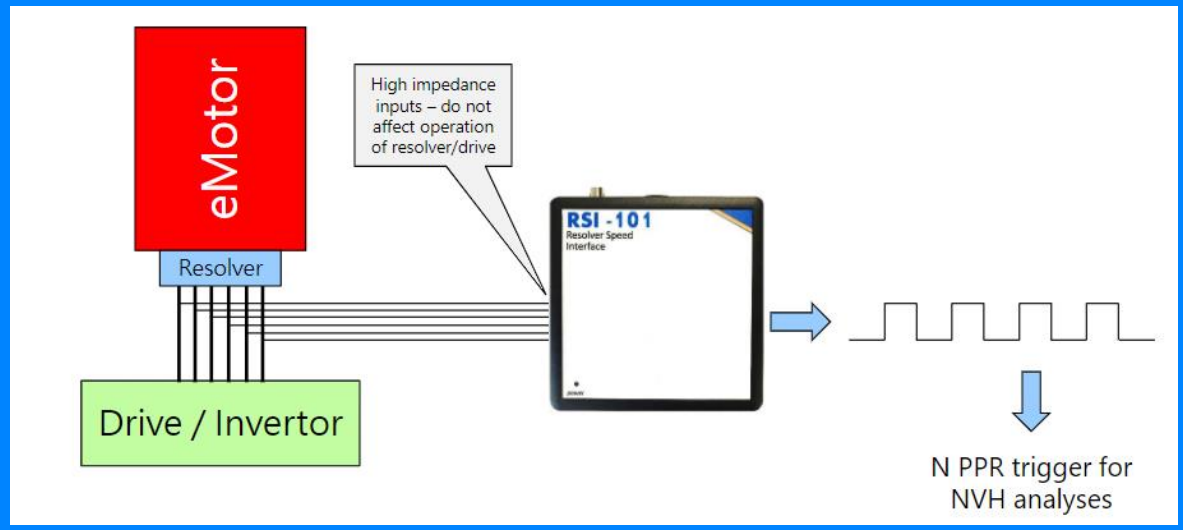
ePowertrain Feature	NVH Issue(s)	Method / Remarks
Reduction gears, differential	(1) Mesh orders (2) harmonics & (3) sidebands	Order analysis, at high rotation speeds (RPM)
E-motor	(4) Rotor imbalance (5) Slot orders & harmonics	
Bearings	Race and rolling-element defect, misaligned assembly	Speed synchronised envelope analysis
Casing	(6) Structural resonance(s)	Frequency analysis
Invertor	(7) Base frequency e.g. 8kHz, sidebands and harmonics	Frequency & speed related analysis for sidebands

Electric/Hybrid (ePowertrain) NVH (Pt.2)

- eMotor rotation speed (RPM) required for:
- Order analyses.
- Speed-synchronised envelope analyses.

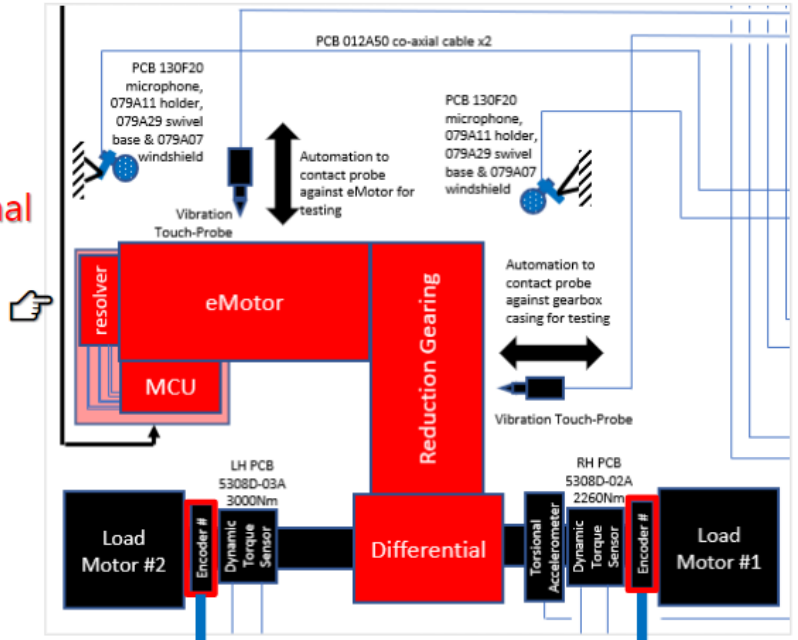
NVHI's RSI-101(Resolver Speed Interface) module:

- Intercepts resolver signals (excitation, sine output, cosine output).
- Converts to N pulses/revolution.



"Twin-Tacho" Order-Tracking for ePowertrain EOL Testing

No access to eMotor speed signal (resolver wiring encapsulated)



PRD-102 optional to rate-divide higher pulse-rate encoders e.g., 2048 PPR load motor encoders /8 = 256 PPR (ideal for twin-tacho technique)

Circa 256...512 PPR

PLATO

- Synthesises eMotor speed in real-time
- Order analysis referenced to eMotor
- Accommodates differential speeds

e-Kit add-on for Electric/Hybrid –Functional /Electrical Tests

In addition to NVH testing, ePowertrain assemblies may also require functional/electrical tests to be performed as part of an end-of-line test e.g.

• Temperature sensor(s) verification.	• **Gear-shift motor and fork calibration.**	• **Motor Phase Order**
• Connectivity of switches.	• **Resolver offset angle.**	• **Mechanical efficiency(unpowered coast-down friction).**
• Equipotential bonding.	• **Resolver transformation ratio.**	• Gear shift verification.
• Electrical isolation resistance.	• **Resolver output linearity.**	• Limited-slip differential operation.
• Withstanding voltage.	• **Motor back-EMF (winding QA & balance).**	• **Backlash** (using METKIT add-on –see slide 29).

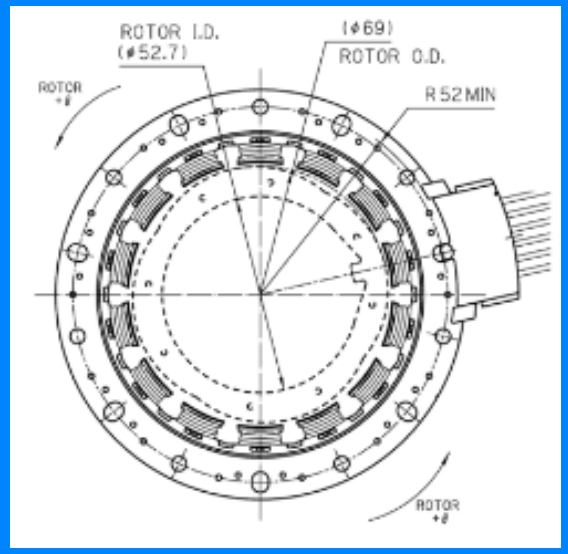
Code:
White = typically performed by the test machine / PLC
Orange = specific analyses available within PLATO
Green = if access available to resolver output signal (analogue or via inverter firmware)

e-Kit Resolver Offset Angle & Transformation Ratio

Revolver Offset

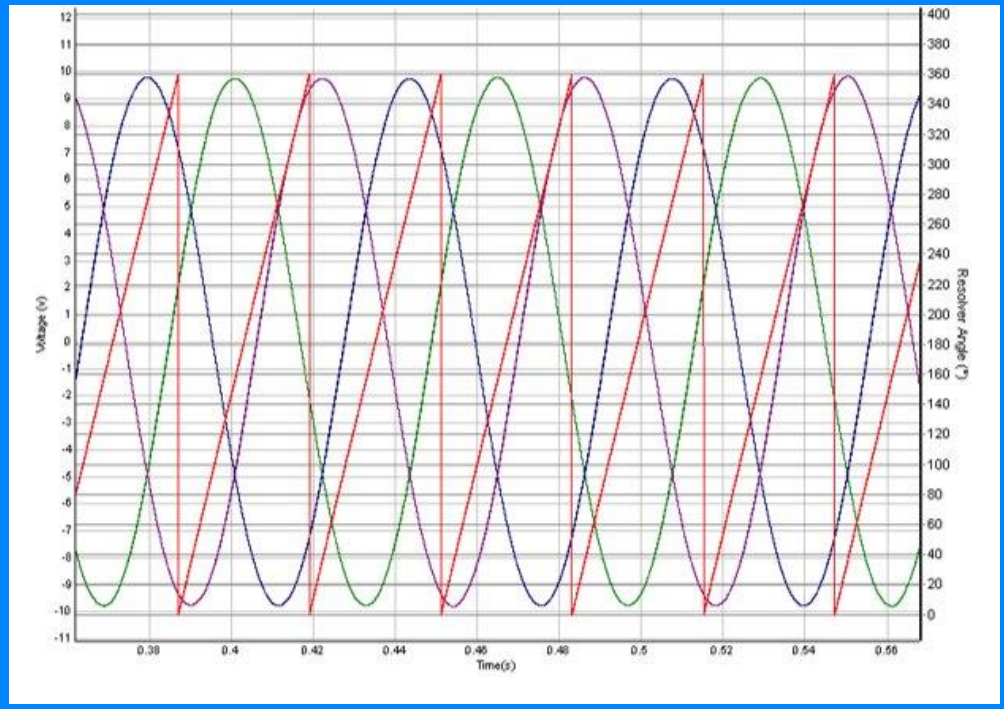
Simultaneous measurement of:

- eMotor winding voltages.
- Resolver output signals to establish angular offset between true zeros on each device.
- Essential information for optimum eMotor control.



Transformation Ratios

Measured and reported for SINE and COSINE resolver outputs relative to resolver EXCITATION.



TEST STAGE RESULTS: Revolver Offset Measure

PARAMETER NAME	MIN (°)	MEAN (°)	MAX (°)	SINE XFORM RATIO	COSINE XFORM RATIO	PASS/FAIL
Parameter #1	22.7817	23.6664	24.1291	0.2859	0.2857	PASS

NVH INTERNATIONAL

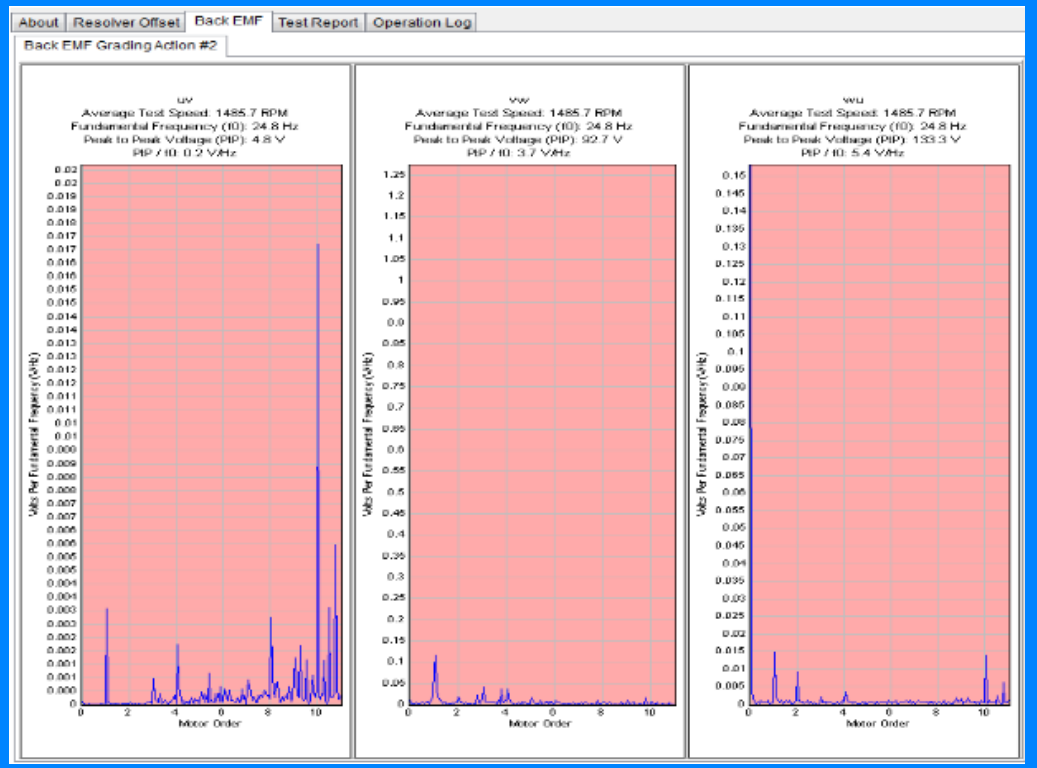
e-Kit eMotor Back-EMF Analyses

- Winding QA (manufacturing/assembly faults determined by back-EMF waveform analysis).
- eMotor driven by test machine motor(s).
- Simultaneous differential measurement of eMotor windings (UV, VW, WU) with:
  - Harmonic order analysis.
  - Pass/fail assignment.
  - Reporting.

TEST STAGE RESULTS:Back EMF Measure

MOTOR BACK EMF

PARAMETER NAME	Thermal Coeff [mT]	Fund Freq [f0]	Measurement	Value (V)	Value/f0 (V/Hz)
uv	1.0000	24.7617	Peak to Peak	4.7623	0.1923
			Fund x1 Amp	0.0892	0.0036
			Fund x2 Amp	0.0115	0.0005
			Fund x3 Amp	0.0335	0.0014
			Fund x4 Amp	0.0314	0.0013
			Fund x5 Amp	0.0228	0.0009
			Fund x6 Amp	0.0050	0.0002
			Fund x7 Amp	0.0575	0.0023
			Fund x8 Amp	0.2200	0.0089
			Fund x9 Amp	0.3141	0.0127
			Fund x10 Amp	0.3472	0.0140

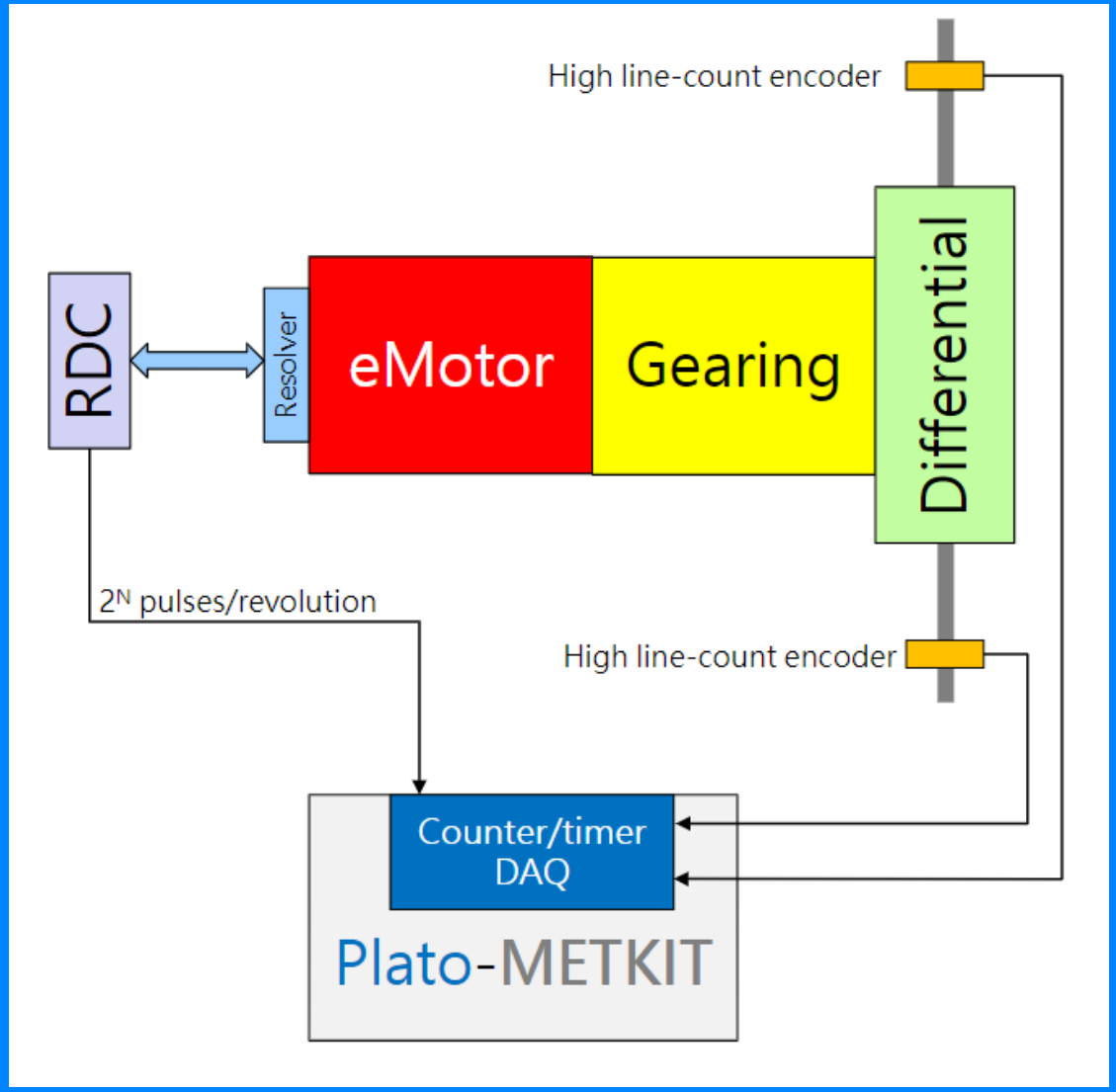


NVH INTERNATIONAL

METKIT Backlash Measurement

Overall ePowertrain backlash measured using:

- Resolver-Digital Convertor (RDC).
- Output shaft-driven, high line-count encoders.
- High-speed counter/timer data acquisition hardware.
- **METKIT** add-on software from NVH International.

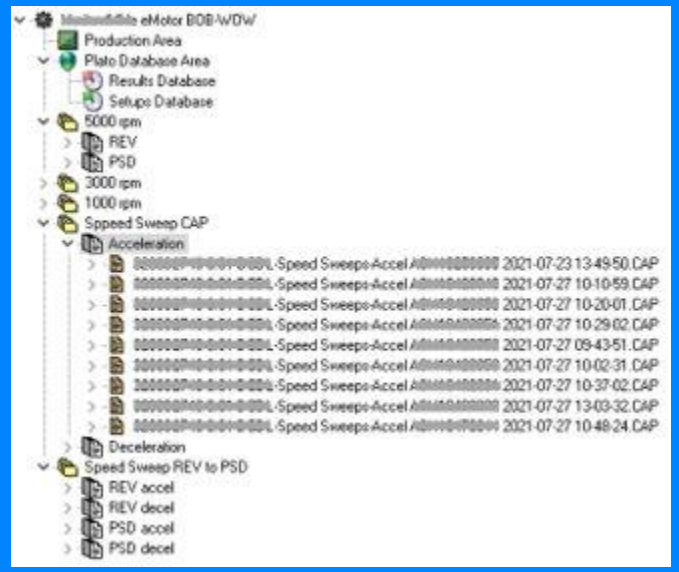


NVH INTERNATIONAL

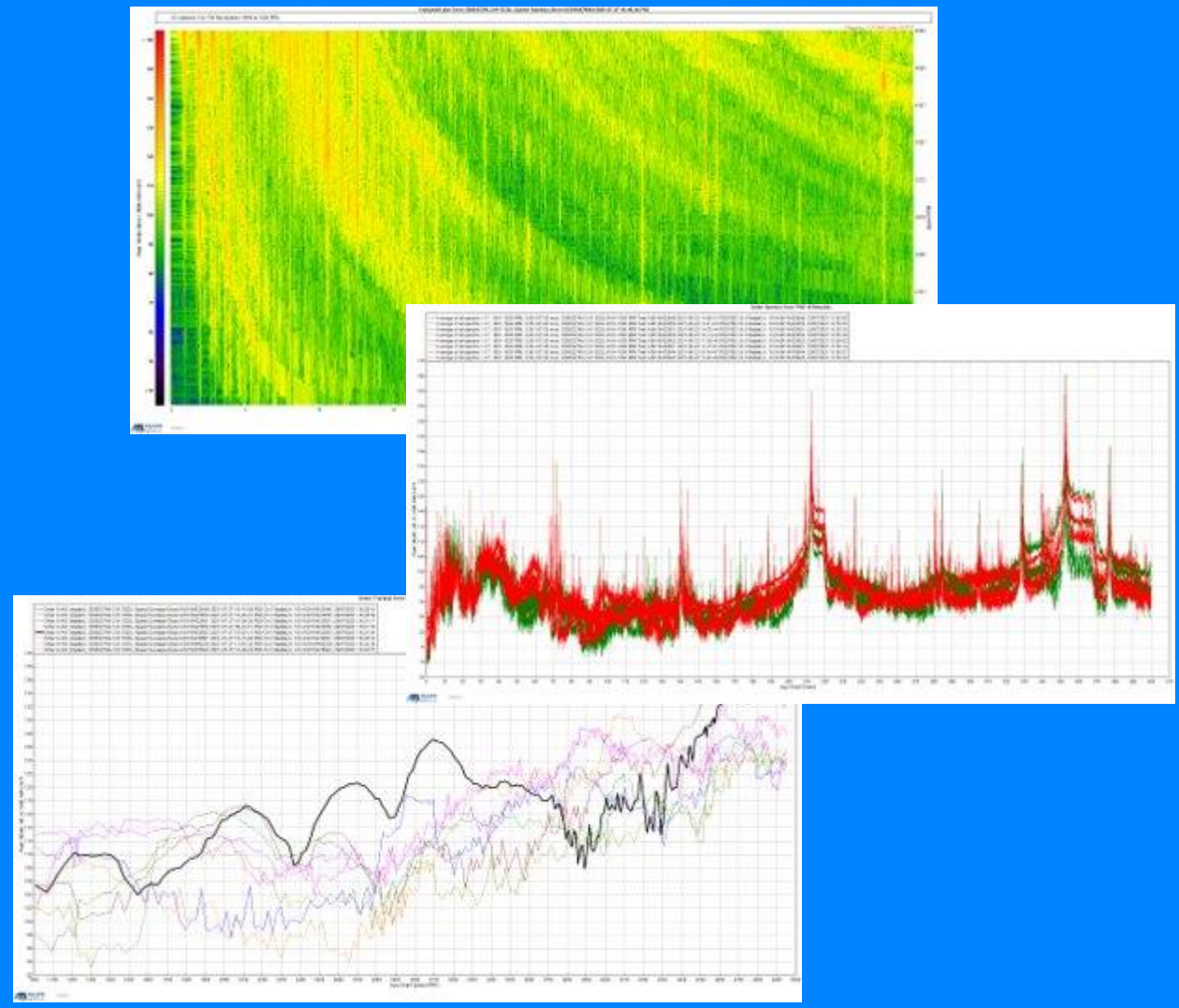
Plato Analysis Licence(s) - PALs

All PLATO functionally available, except data capture.

Access & edit PLATO Projects from test machines.

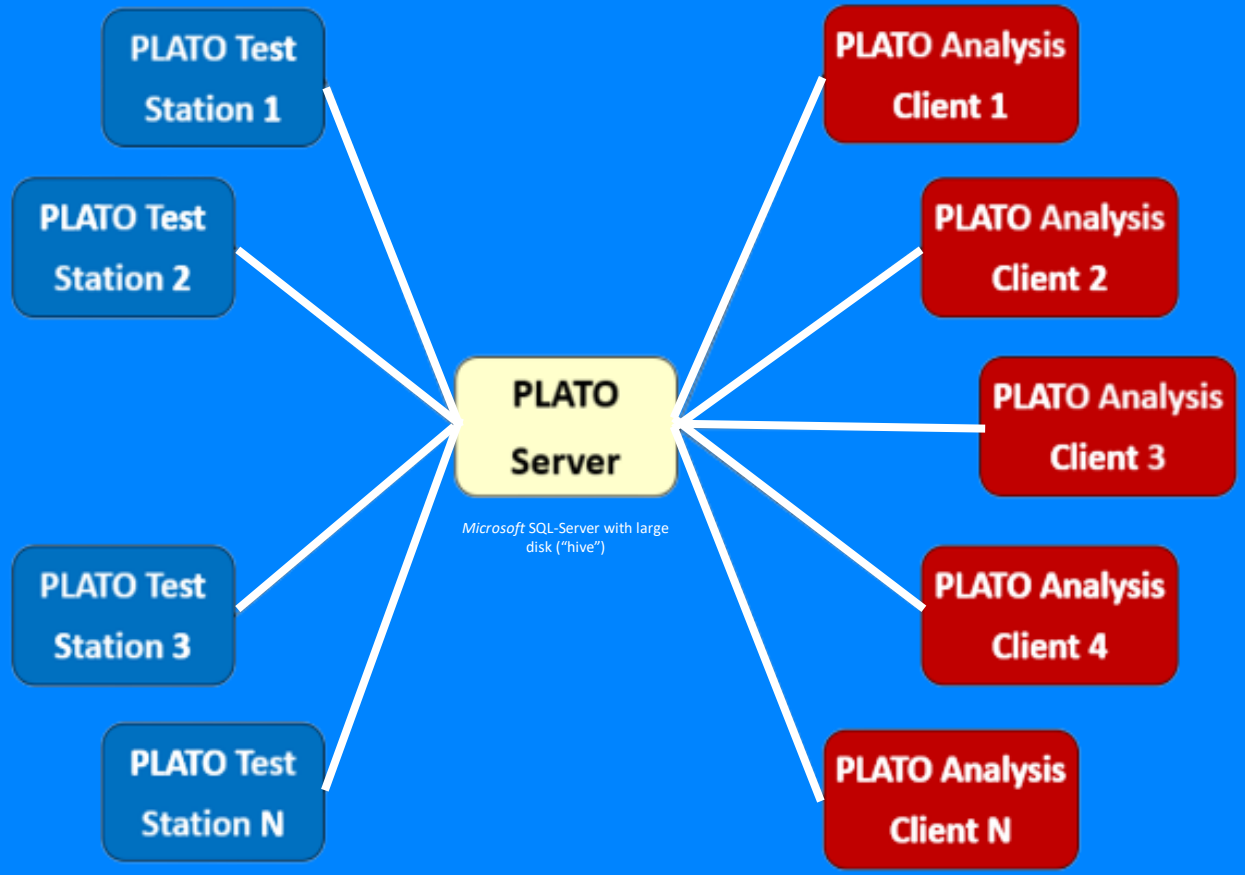


Create analysis/reporting projects.



PALs are available free-of-charge to an unlimited number of users associated with the operation of data capture-based PLATO test systems.

PLATO-Server



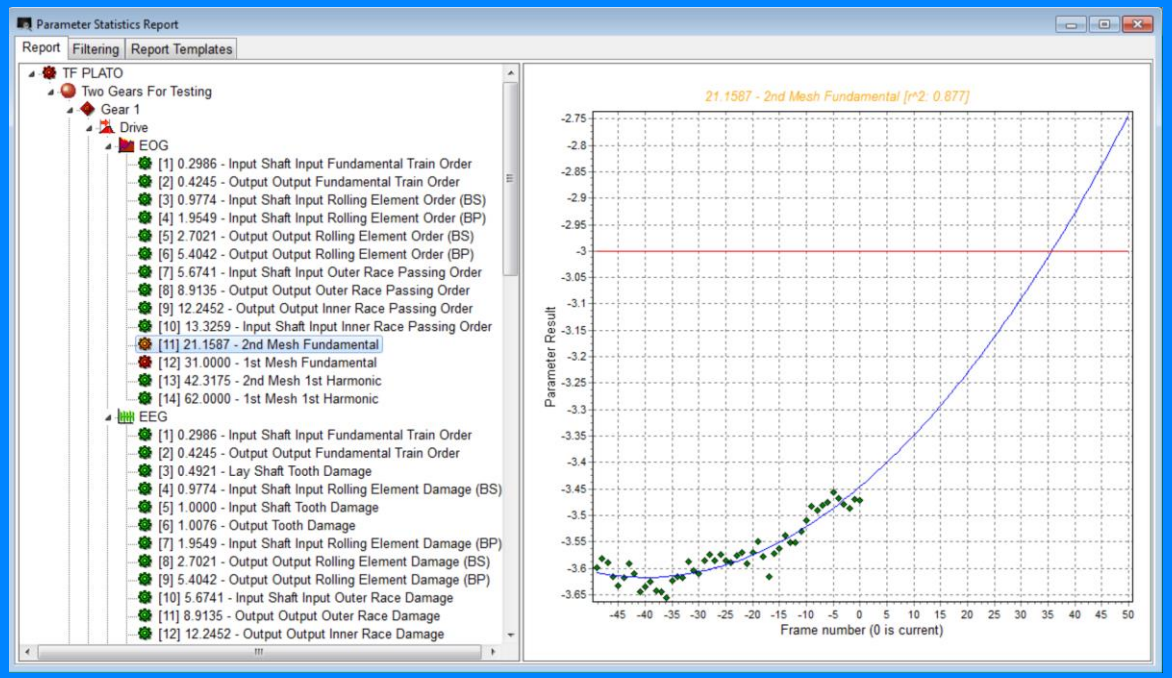
PLATO-Server software and configuration services provided **free-of-charge.**

- Network, server hardware/operating system and SQL-Server provided by customer.

NVH INTERNATIONAL

Plato Analysis Client (PAC)

- Free-of-charge software installed on users' PCs that are networked to Plato-SERVER.
- Analysis for single test stations or aggregated across N test stations.



Easily review quality trends in all measured features.

Retrieve any Test Reports from your network-connected PC.

Images are optional if made available in nominated folder on disk prior to Transfer Client sending results to SERVER.

PLATO from NVH International Engineers:

• PLATO is designed, developed and supported throughout the lifetime of your powertrain/steering product testing by **ENGINEERS** who:

- **Liaise** with your engineers daily.
- **Understand** your products.
- **Understand** the manufacturing processes involved.
- Have **first-hand experience** of where manufacturing can go wrong, and how this translates to noise/vibration output.

PLATO from NVH International – why choose us over our competitors?

- Open, Intuitive & Transparent Software/Set-up.
- Worldwide Standard **NI™(National Instruments)** Hardware (supplied by you if prefer).
- Modular Software > Flexibility to Re-purpose in the Future.
- Parallel Analyses > Fast Cycle Times.
- Easy (OPC-software) Communications with Test Machines.
- Easy Result Export to Factory Information Systems (SQL-queries or OPC).
- 1stClass Support:
  - From regional offices and in-territory technical representatives.
  - Real-time via Internet from NVHI.

1985

First system for end-of-line NVH testing of Range Rover Classic 4x4 Transfer Cases.

Installations Worldwide

(UK, Germany, Austria, Argentina, France, Poland, USA, Mexico, Brazil, India, China, South Africa, Turkey, Korea, Sweden)

37 years

Testing transmissions, axles, transfer cases, PTUs, eMotors, eDrives, powertrains, bearings, power-steering systems.

2022

Solid, reliable and meaningful systems in use 24/7.

NVH INTERNATIONAL

Some of our PLATO NVH customers worldwide:

Detailed installation reference list available on request!

NVH International PLATO is preferred by many of the world's largest powertrain manufacturers

AAM	Preferred NVH system supplier worldwide	**45 systems** deployed and operational(China, Poland, Mexico, USA, Korea)
DANA	≈50% NVH system supplier worldwide	**23 systems** deployed and operational(Argentina, China, Hungary, South Africa, Sweden, UK, USA)
GKN AUTOMOTIVE	Preferred NVH system supplier (USA)	**15 systems** deployed and operational(China, USA)
MERITOR	Preferred NVH system supplier (USA)	**9 systems** deployed and operational(USA)

Detailed installation reference list available on request!

NVH INTERNATIONAL

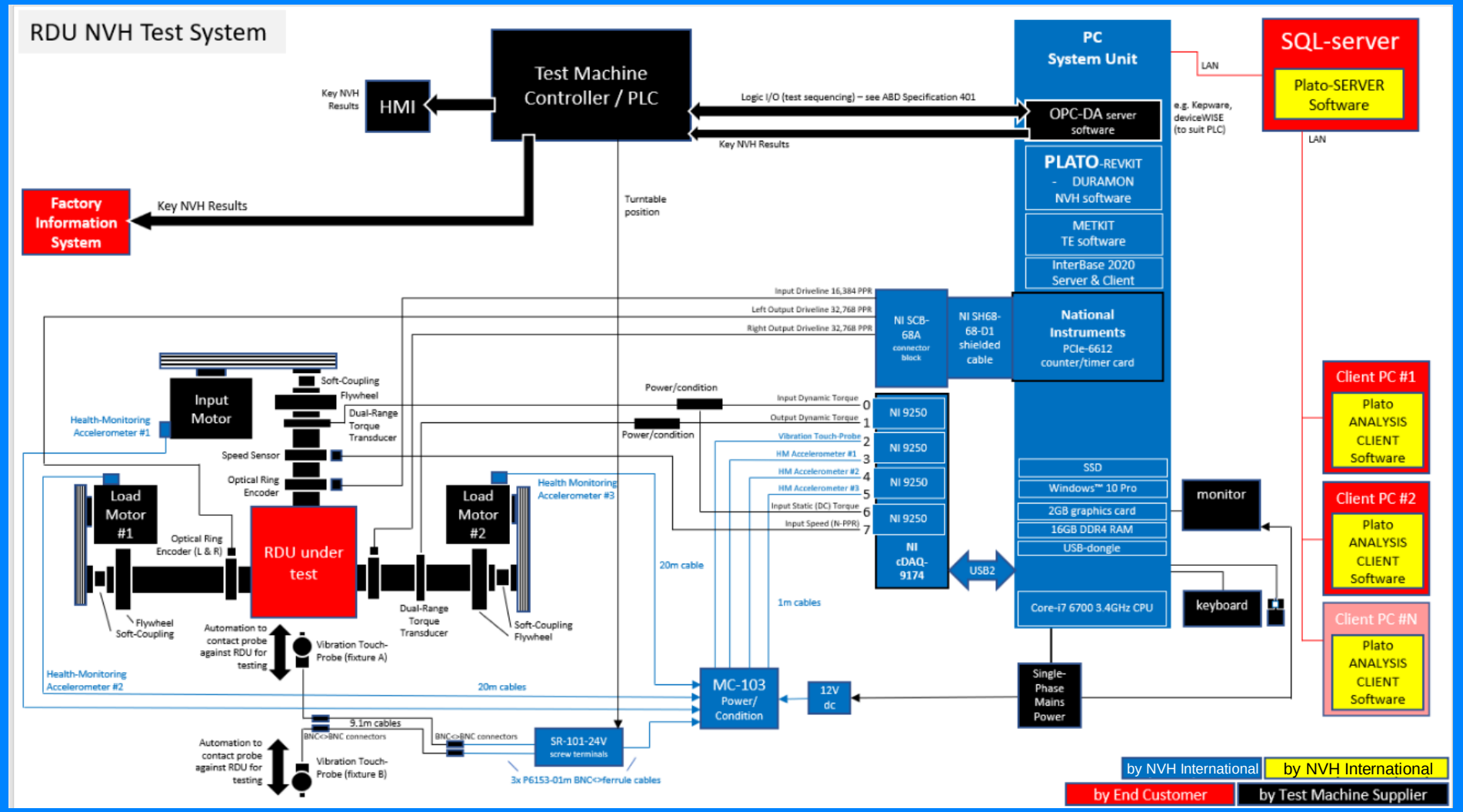
Successful NVH system integrations with test machine suppliers worldwide:

Austria - Kristl, Seibt & Co.	Taiwan – Sentek Automation, Chutung
Belgium - BEP Europe	United Kingdom – Expert Tooling & Automation Ltd.
China - BEP (China) Testing Equipment – Wuxi	United Kingdom – Horiba Instruments Ltd.
China - Bestone Group – Qingdao, Shandong	United Kingdom – George Kingsbury Machine Tools Ltd.
China - GD Steady (Dti – Detroit Technologies Innovation)	United Kingdom – Schenck Test Automation Ltd.
China - HHZN aka Anhui HangDa Intelligent Technology Co. Ltd. (HDZN) – Hefei	USA – ATW (ex AT&T [DT – Industries])
China - TCX – Beijing Taichengxin Measurement & Control Technology	USA – Epic Equipment & Engineering
Germany - Teamtechnik Maschinen und Aniagen GmbH	USA – Merritech (Merrill Tool Holding)
Germany – Siemens	USA – Burke E. Porter Machinery Co.
India - Winstar Hydraulics Pvt LTD, Chennai	USA – Schenck Test Automation Ltd.
Mexico - Transmisiones y Equipos Mecanicos, S .A. de C.V (“Tremec”)	USA – Sytech (Cummins)
Poland - CIMAT Sp. Z.o.o.	USA – Gleason (Modified Machines)
Sweden - Sejfo Engineering / IT AB, Köping	

Detailed installation reference list available on request!

NVH INTERNATIONAL

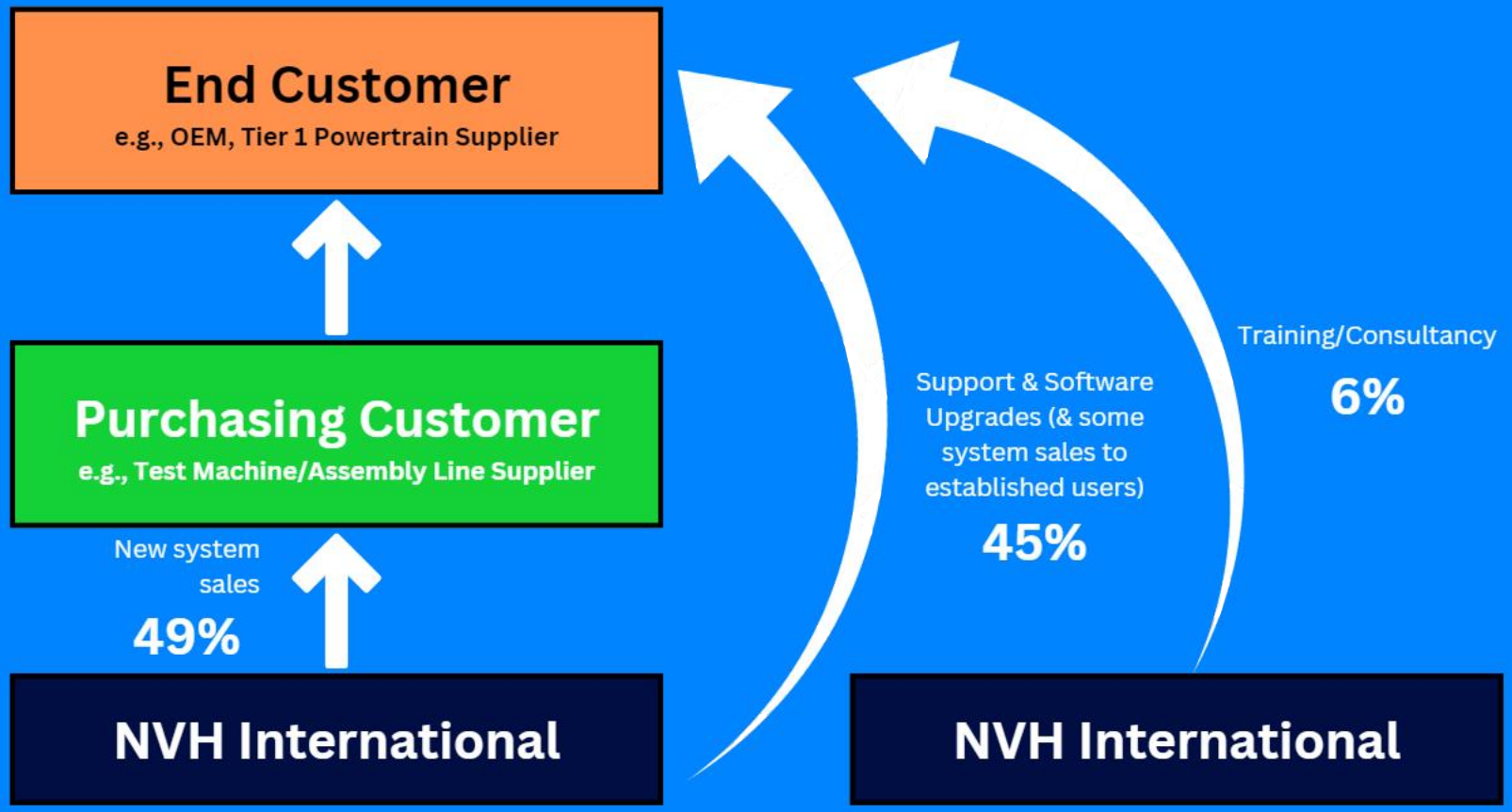
Typical PLATO-based NVH test system (simplified) schematic:



Scope of supply (responsibilities) clearly identified at RFQ/quotation stage.

NVH INTERNATIONAL

Sales Routes:



NVH INTERNATIONAL

Thank you!

Get in touch with us...
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