



# Rolls-Royce

## **Dynamic Measurement Challenges: An Industry View**

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### **BIPM Workshop on Dynamic Measurement**

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# Outline

- Measurement in Rolls-Royce
- Definition of dynamic measurements
- Where do dynamic measurements arise?
- Drivers towards more dynamic measurements
- How to treat dynamic measurements
- Potential contribution of the International Metrology Community
- Conclusion



# Essential power delivered globally

## Civil aerospace

- our engines are keeping up to 400,000 people in the air at any one time

## Defence aerospace

- 160 armed forces depend on our engines

## Marine

- 30,000 commercial and naval vessels use our marine equipment

## Energy

- powering customers in 120 countries in electricity and oil and gas markets



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# Rolls-Royce - Group profile

Our ability to design and develop high-technology products and then integrate these into sophisticated power systems for land, sea and air, provides us with access to global markets.

Trusted to deliver excellence

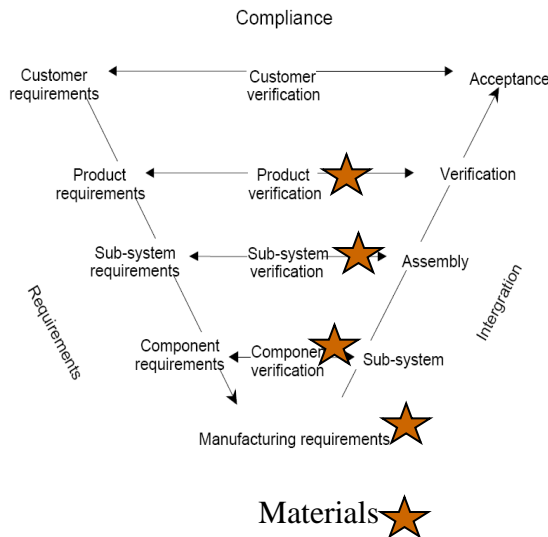


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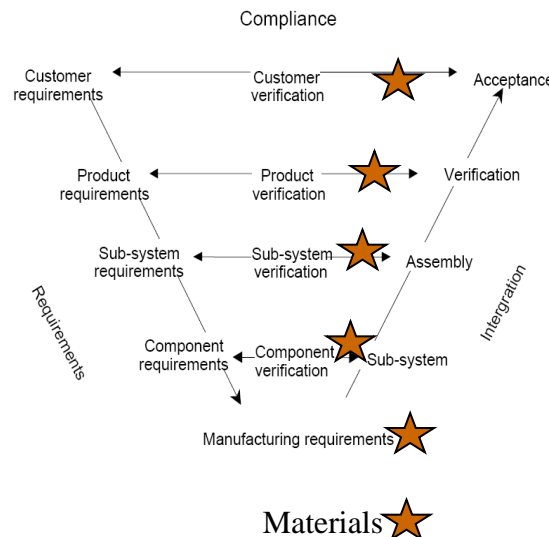
# Where is Measurement Used?

- Throughout Design, Manufacture, Operation and Disposal

## Design Models



## Product



## Service



+ Sensing for control of product, manufacturing, maintenance and disposal processes: - ★

# Definition

For the purposes of this paper:

We treat measurements as “dynamic” when:

The rate of change of the quantity value impacts the metrology.

Therefore a measurement system with infinite bandwidth which faithfully reproduces amplitude and phase of the parameter is not dynamic!

However, a system measuring changes occurring over several hours may be dynamic if it's bandwidth is insufficient for the task



How do we know?



There are two steps to consider:

First we must determine whether we can be confident that the bandwidth is adequate

Second, if it is not, we must determine the influence of this limitation on the metrology



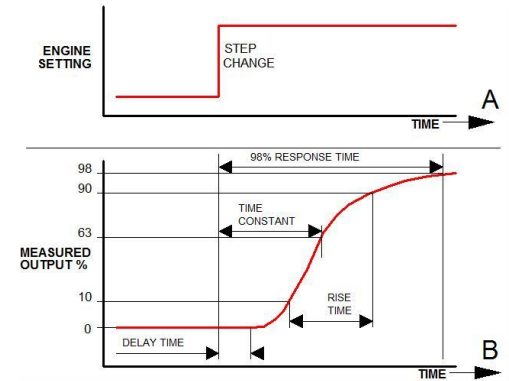
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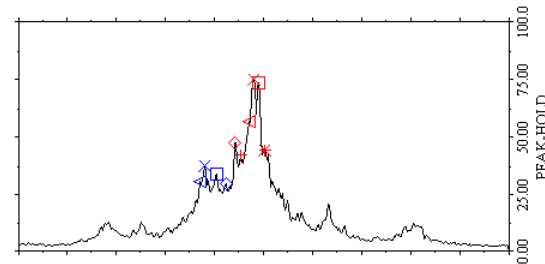
# Where do dynamic measurements arise?

## *Machinery examples:*

Transient manoeuvres – time domain



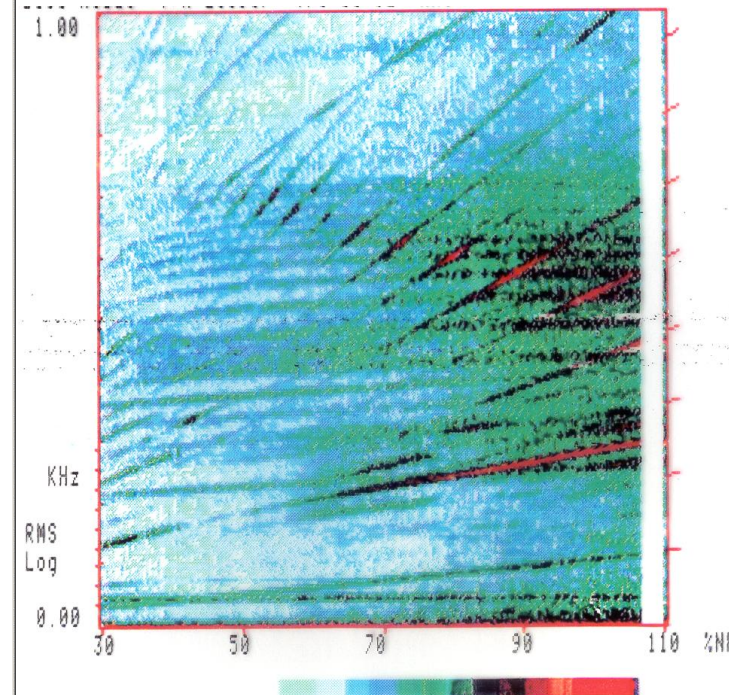
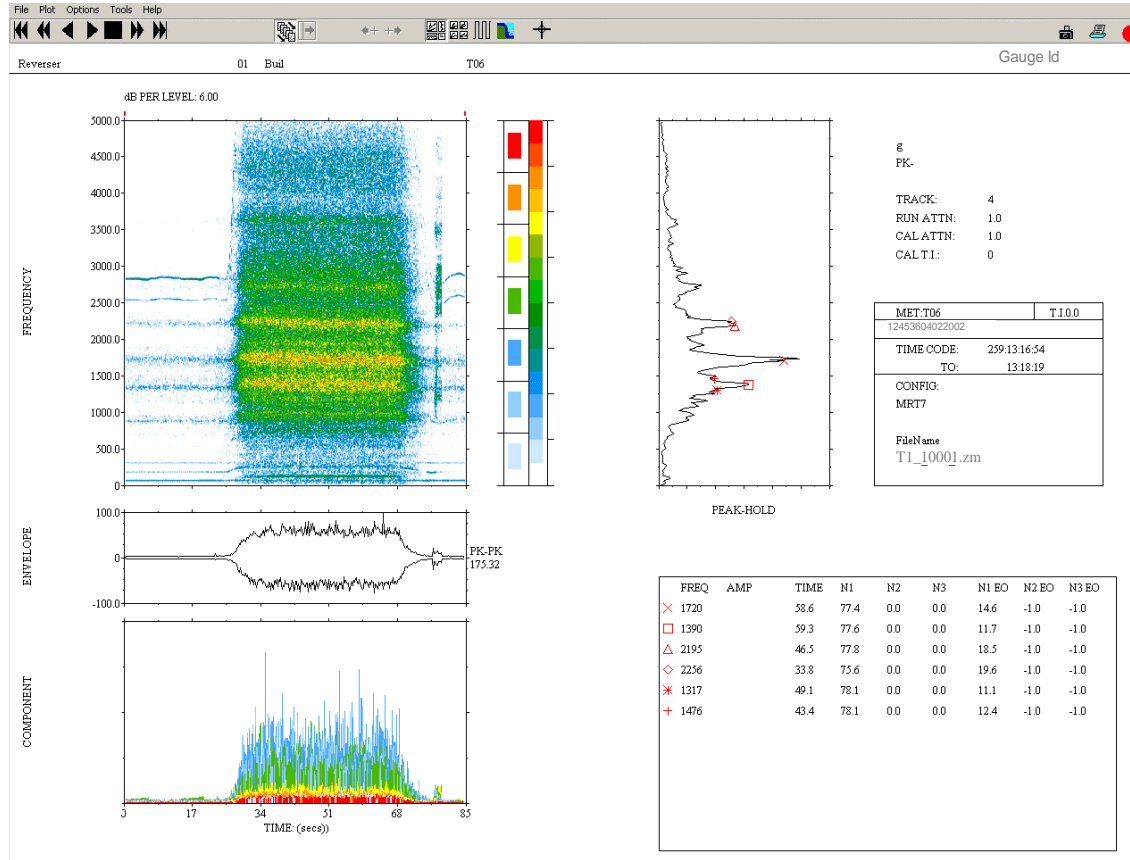
Vibration – frequency domain



Pseudo steady-state – unsteady effects - DoE



# Typical Dynamic data visualisations



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# Drivers towards more dynamic measurements



Reducing margins – 2<sup>nd</sup> order effects

Demand to sense fast transient events

Faster processes in manufacturing

Miniaturisation e.g. MEMS

“Because we can”



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# How to treat dynamic measurements

- Clarity on the information needed to make decisions
- Understanding of the characteristics of the measurand – e.g. stationarity of data
- Risk of bandwidth limitations affecting the metrology
- Feasibility of dynamic calibration
- System design and calibration planning
- Uncertainty analysis pre & post test



# How to treat dynamic measurements – Pragmatic compromise

Many dynamic measurements have a long history



It was impractical to formally assess the uncertainty of past systems

Allowance was made for the limitations of system performance in the down-stream application of the data

Moves to introduce greater rigour need to be mindful of this legacy.

# Potential contribution of the International Metrology Community

Engage with Industry at “System Level”

Consider in-situ calibration

Generic tools

Standards

MUA approach

Case studies



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# Conclusions

- The need for dynamic measurements in industry is critical and growing
- The metrology of dynamic systems is not well understood or documented
- Considerable pragmatism in approach is required
- There is an opportunity for the International Metrology Community to lead improvements in Industry provided it is sensitive to the context.



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