



PREDICTIVE FEASIBILITY

PFA

Real-World Validation Case 02

Recoverable Structure Hidden Inside a Non-Predictive Signal

Question

Can a signal that initially appears non-predictive become suitable for predictive modeling after representation recovery?

Classification Summary

Representation	Classification
Raw Time Domain	NO-GO
Full Frequency Spectrum	LIMITED
Physically Aligned Frequency Band	Near GO

Key Insight

The signal did not change.

The representation changed.

Initial Observation

This question was investigated using real-world industrial vibration data.

The raw time-domain signal initially appeared highly active and structurally rich. At first glance, the signal seemed suitable for predictive modeling.

The raw signal exhibited:

- High signal energy
- Visible structural activity
- Strong local variation
- Apparent complexity

Despite this, cross-run reproducibility remained extremely low.

Initial Classification:

NO-GO

The signal did not support stable predictive deployment.

Representation Recovery

Instead of immediately abandoning the signal, additional analysis was performed.

The signal was evaluated through:

- Frequency-domain transformation
- Spectral isolation
- Physically meaningful frequency selection

As the representation became better aligned with the underlying system physics, predictive structure began to emerge.

Result

Raw Time Domain

Cross-run consistency remained near zero.

Classification: NO-GO

Full Frequency Spectrum

Partial reproducibility emerged.

Classification: LIMITED

Physically Aligned Frequency Band

Strong cross-run alignment became visible.

Classification: Near GO

Figure 1 — Recovery of Predictive Structure

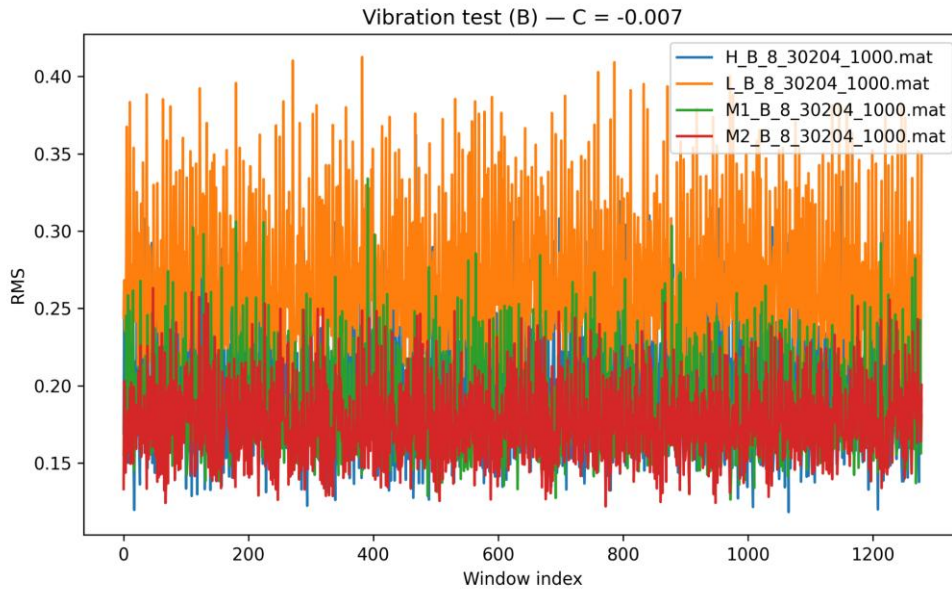


Figure 1. Despite visible structure and high signal energy, cross-run consistency collapses ($C \approx 0$), indicating absence of a stable mapping across runs.

Absence of Stable Regimes

Sliding consistency analysis demonstrates that the signal never enters a stable predictive regime over time.

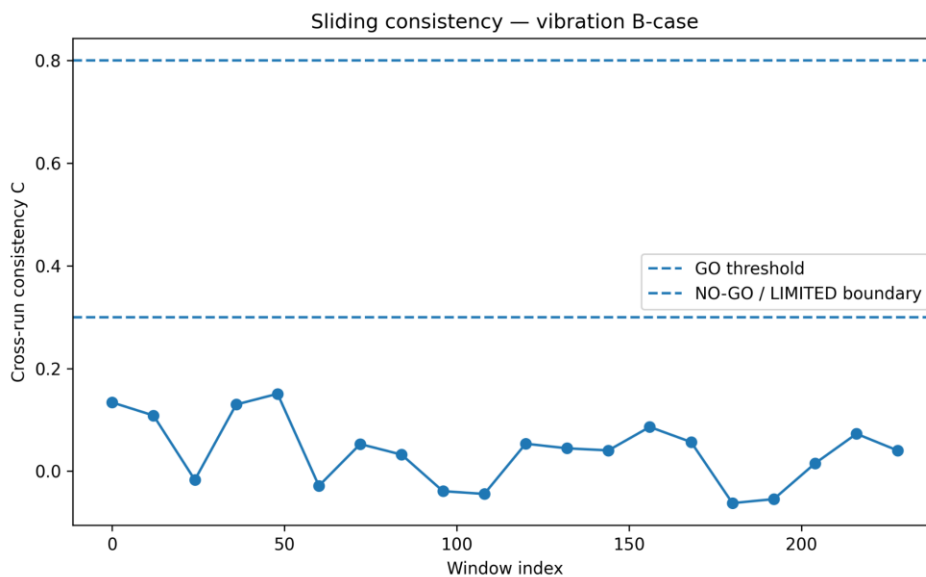


Figure 2. Sliding consistency remains near zero across all time windows, confirming that instability is structural rather than local or transient.

Transition Toward Recoverable Structure

Although the time-domain signal behaves as a clear NO-GO case, the key question becomes whether predictive structure exists in another representation aligned more closely with the underlying system physics.

LIMITED — Frequency-Domain Recovery

Moving into the frequency domain reveals partial reproducibility. The signal contains recoverable structure, but the mapping remains unstable.

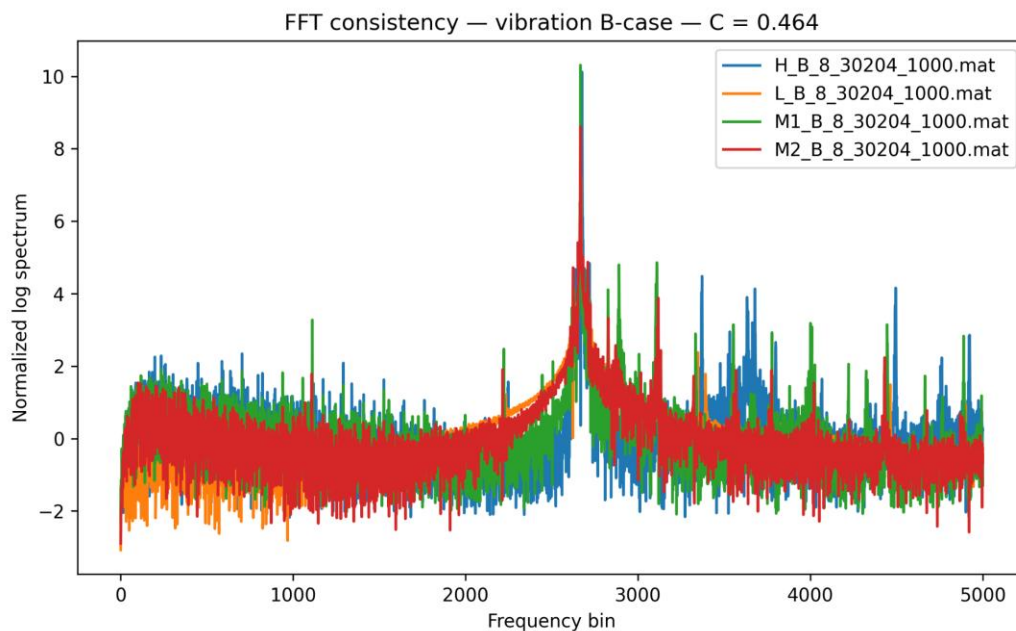


Figure 3. Full-spectrum FFT reveals partial cross-run consistency ($C \approx 0.46$), indicating that predictive structure exists but remains unstable.

Near-GO — Physically Aligned Frequency Band

Restricting analysis to a physically meaningful frequency band significantly increases cross-run alignment, revealing near-stable predictive structure.

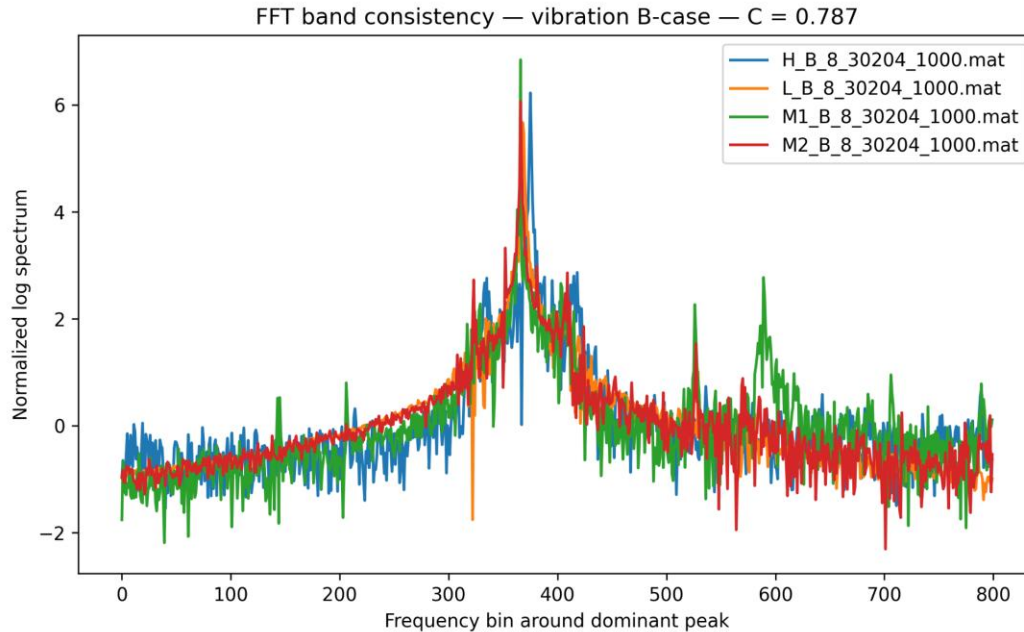


Figure 4. Focusing on a narrow frequency band around the dominant spectral peak increases cross-run consistency to $C \approx 0.79$, revealing a nearly stable mapping.

Recoverable Structure vs Temporary Alignment

Not all apparent improvements in predictive behavior correspond to genuine predictive structure.

In several evaluated systems, localized increases in consistency emerged under specific:

- operating conditions
- signal representations
- frequency-domain transformations
- or restricted state regions.

However, further analysis revealed that many of these consistency peaks were caused by temporary alignment effects rather than stable predictive structure.

This leads to an important distinction:

- Recoverable structure

Stable reproducible structure exists and can emerge under improved representation aligned with underlying system physics.

- Temporary alignment

Signals become locally similar under constrained conditions, but the structure does not persist across the operational range.

This explains why predictive models may appear highly successful in limited operating regions while failing during broader deployment.

Reliable predictive feasibility requires persistent reproducible structure, not transient alignment.

In several evaluated systems, recoverable structure only emerged after the signal representation became better aligned with the underlying system dynamics. This suggests that predictive feasibility may depend not only on the presence of structure itself, but also on whether the chosen representation preserves the mapping between observable behavior and system progression.

Industrial Implication

A signal that initially appears unusable may still contain valuable predictive information.

Raw Time Domain:

NO-GO

↓

Full Frequency Spectrum:

LIMITED

↓

Physically Aligned Frequency Band:

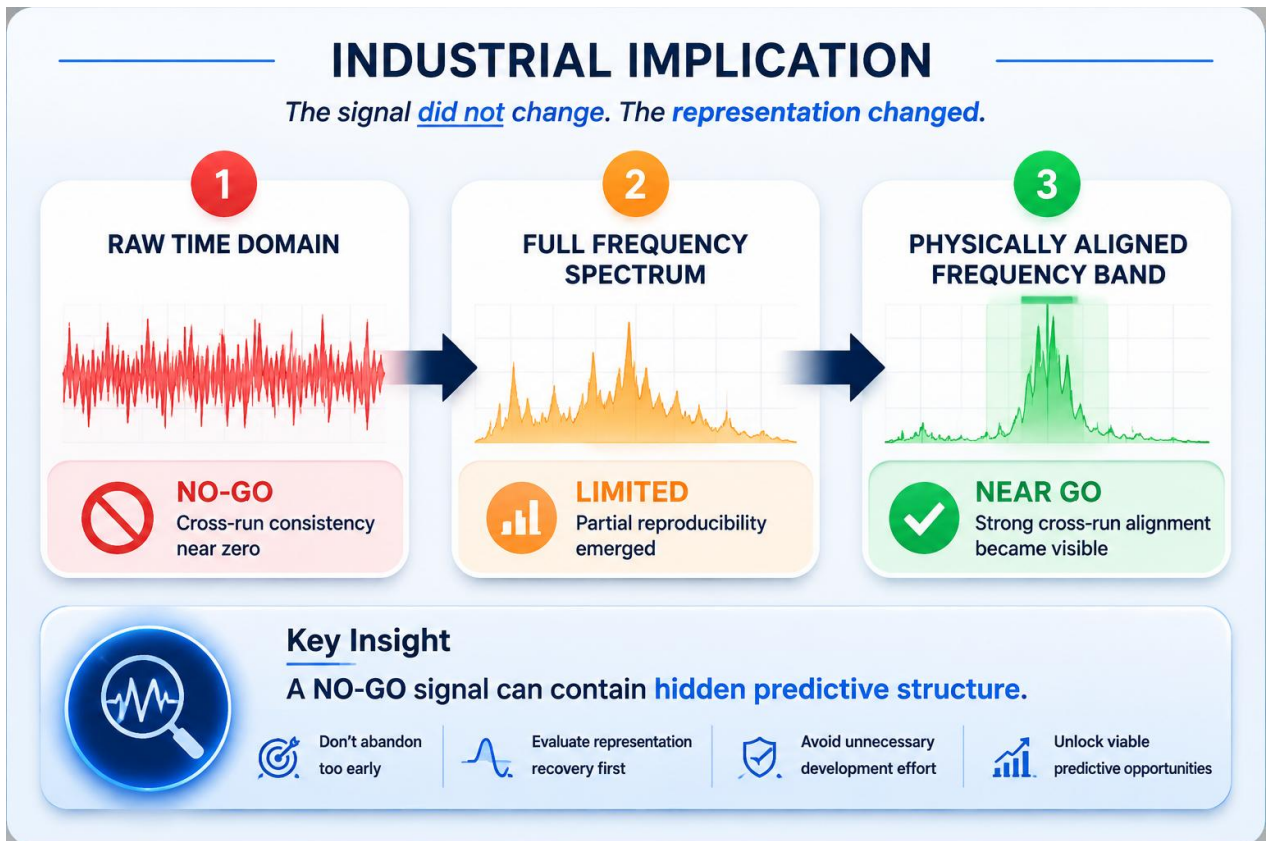
Near GO

The signal itself did not change.

The representation changed.

This demonstrates that predictive feasibility is not determined solely by the observable signal, but also by how effectively the representation captures the underlying system dynamics.

Evaluating representation recovery before abandoning a signal can prevent the loss of viable predictive opportunities and avoid unnecessary redevelopment efforts.



Why This Matters

Many predictive systems are abandoned too early.

This case demonstrates that some signals are not fundamentally non-predictive.

Instead, predictive structure may be hidden within an unsuitable representation.

A signal that appears non-viable in one representation may become operationally useful when evaluated through a representation that better reflects the underlying physics of the system.

Key Takeaway

A NO-GO signal does not always mean prediction is impossible.

Sometimes the predictive structure is present, but hidden.

The challenge is identifying whether the signal contains recoverable structure before investing in large-scale model development.

In this case, predictive structure was not recovered by a better model.

Predictive structure was recovered by a better representation.