Model-based Diagnostics:

Design-based vs. Empirical-based

The label “Model-based Diagnostics” is used to describe widely divergent diagnostic approaches. MBD can refer to diagnostics derived directly from engineering data (“Design-based”) or to diagnostics developed over time by recording the resolution of failures in a deployed or operational system (“Empirical-based”). Through the accumulation of symptomatic knowledge from fielded systems, Empirical-based diagnostics are theoretically able to get “smarter” over time. The allure of a diagnostic model that can learn to overcome its initial deficiencies is so strong that it can cause those who fall under its spell to cast pragmatism to the wind (much like the “prognostic delusion” of not so long ago).

The fact that Empirical-based diagnostics have a learning curve is embraced as an unequivocal asset. An entire mythology is constructed upon the dream that reasoning from one system might be used to eliminate the learning curve in another. The diagnostic integrity of an operational asset, however, is constrained not only by the design itself, but also by how much attention is given to diagnostic engineering while the design is still in the definition phase. If Design-based diagnostic knowledge is not carried over and integrated with the Empirical-based diagnostics, a “Diagnostic Gap” forms. This issue is illustrated in Figure 1. These two separate / non-integrated diagnostic approaches have differing objectives, capabilities & effectiveness as shown in the bulleted blue and orange lists below.

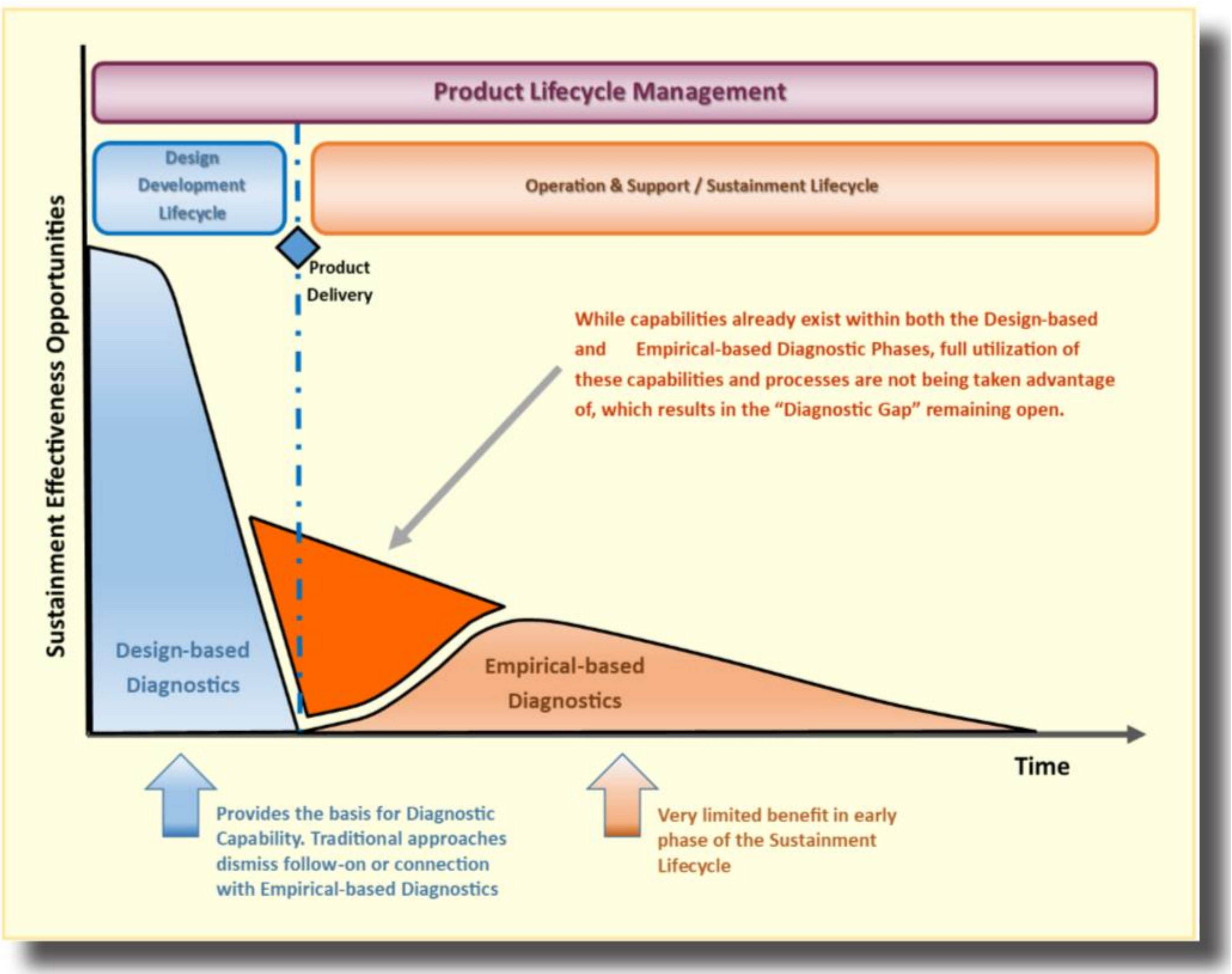

Figure 1 - Current Practice

Design-based diagnostic techniques are widely used both to improve a system's diagnostic design and to assess the ability of diagnostics to meet contract requirements. Inexplicably, many projects discard all "Design-based" diagnostic models entirely when developing run-time diagnostics.

Empirical-based diagnostics are particularly poor when confronted with a failure—even an expected failure—for the first time. This is precisely the situation, however, where Design-based diagnostics shine.

The fact that diagnostic models that already exist can be of immediate benefit should be sufficient for their use as a foundation for fielded diagnostics models that already exist can be of immediate benefit should be sufficient for their use as a foundation for fielded diagnostics.

Design-based Diagnostics

- Knowledge Capture & Design Influence
- MBSE compatible
- Product "Lifecycle" Management – Optimization
- First Failure Accountability
- Model & Data Interoperability/Reusability
- Requirements Traceability
- Multidisciplinary Collaboration
- Iterative Design Assessment & Cross-Validation
- SysML, ATML, NGATS & ATS compatibility
- Diagnostic (Failure-to-Test) & BIT Validation
- Reliability/Supportability/Safety Constraints
- PdM vs. RCM vs. Corrective Maintenance Effectiveness
- RAMS-to-Diagnostic Constraints Time-based Simulations
- Test Paradigm independence
- Sustainment Technology Uniformity and Scalability
- Fully Integrated Health Management
- Proactive approach
- Diagnostic Reasoning
- Diagnostic Certainty
- "Digital Twin" / "Digital Thread" Readied

Empirical-based Diagnostics

Mostly deficient when not coupled with Design-based Diagnostics

- Trending Analyses
- Diagnostic sequence biasing enrichment
- Not able to Influence the design's diagnostic integrity
- Test Methods/Tools Restricted
- Limited Data Reusability
- Restricted Data Interoperability
- First Failure Uncertainty
- Variables Restrict Achievement of High Level Certainty
- Reactive approach
- Diagnostic Correlation
- Diagnostic Uncertainty

On the other hand, situations where Design-based diagnostics fall short, such as when a system fails in an "unexpected" way (due to manufacturing defects, truncated engineering efforts, or environmental idiosyncrasies) are precisely where Empirical-based diagnostics, over time, prove their worth. When the two approaches are viewed not as competitors, but rather as a diagnostic tag-team, integrated diagnostics will begin to fulfill its destiny as a consistent presence during all phases of the product lifecycle.

If one exploits every aspect of design-based diagnostics with a balanced empirical-based diagnostic approach - there is much to be gained.

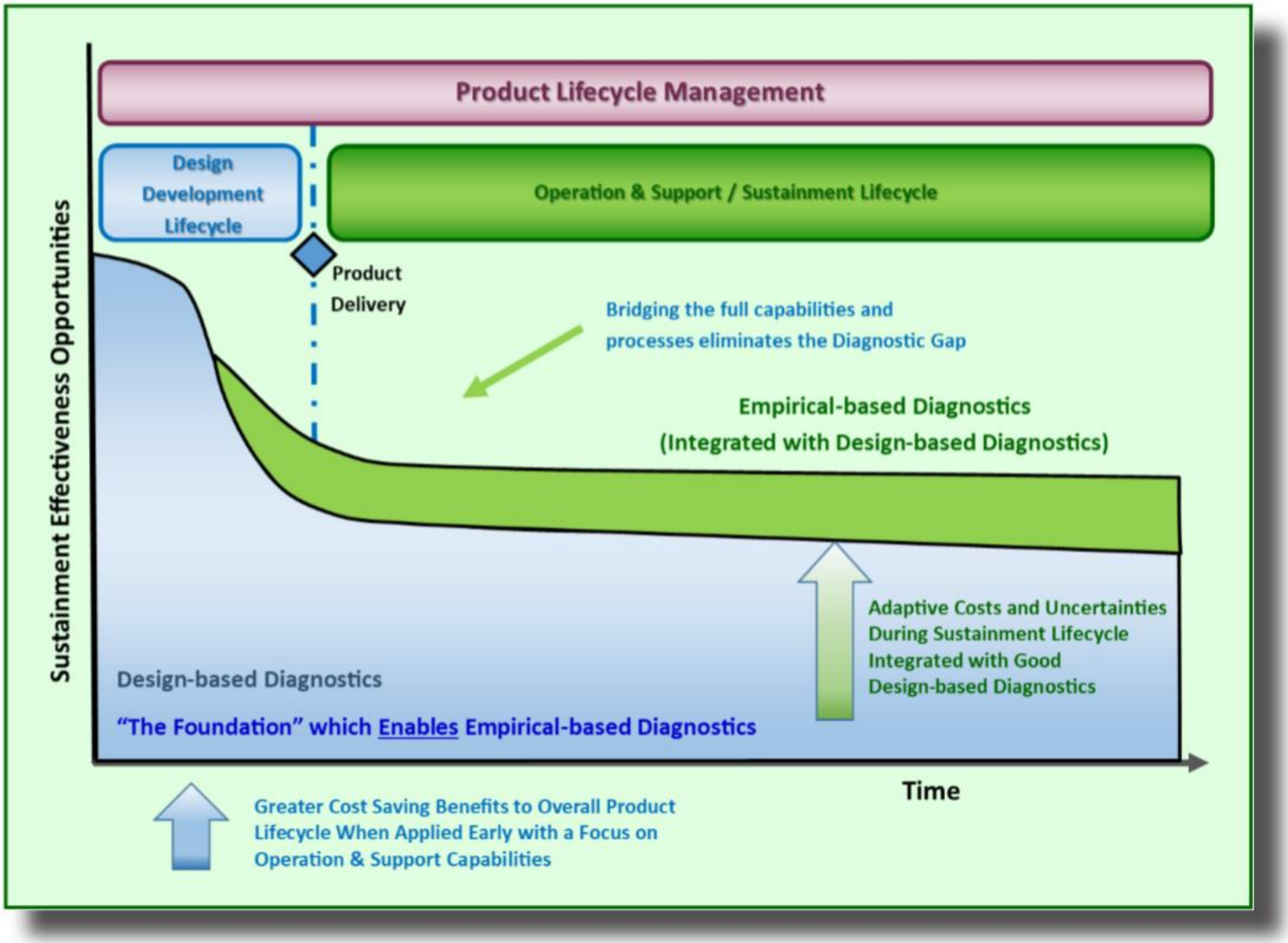

Figure 2 - Optimal Diagnostic Solution

Balanced Approach to Design-Based and Empirical-Based Diagnostics

- Design & Empirical Knowledge Capture & Reuse
- MBSE compatible
- Product "Lifecycle" Management – Optimization
- First Failure Accountability
- Data Analytics & Maturation
- Model & Data-Interoperability
- Requirements Traceability
- SysML, ATML, NGATS & ATS compatibility
- Diagnostic (Failure-to-Test) & BIT Validation
- Reliability/Supportability/Safety Constraints
- PdM vs. RCM vs. Corrective Maintenance Effectiveness
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- Full Reusability
- RAMS-to-Diagnostic Constraints Time Based Simulation
- Diagnostic Certainty
- Trending Analyses
- Diagnostic Sequence Optimization
- Test Methods/Tools Integrated
- "Digital Twin" / "Digital Thread" Readied