Kepstrum
INVENTOR OF PRODUCT DNA™
and MODEL-BASED PROGNOSTICS

PRODUCT DNA™

DESIGN LIMIT NATURE OF FAILURE ACTUAL LIFE

A CURRENT STATE OF THE ART

TRACEABILITY
CONNECTIVITY
REPEATABILITY

PRODUCT DNA HANDBOOK

TABLE OF CONTENTS

MAP YOUR PRODUCT DNA

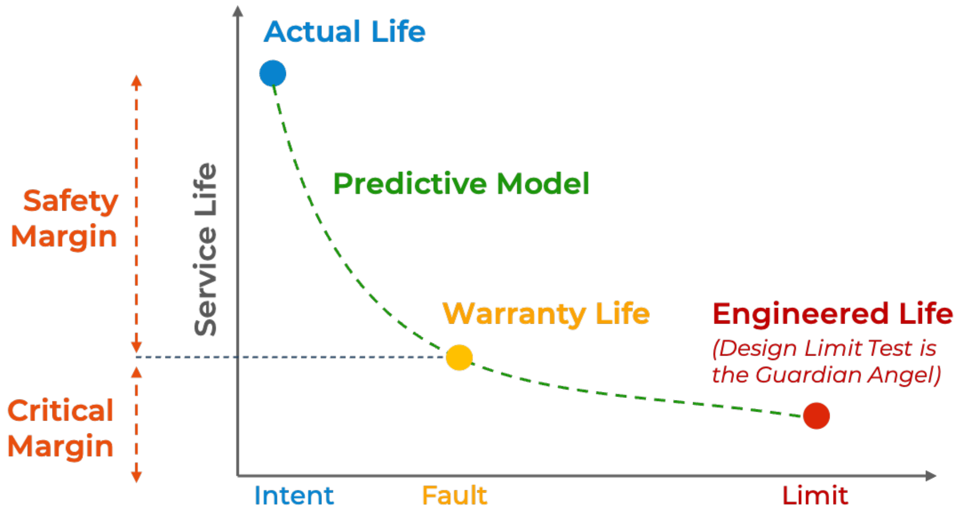
LINK KNOWLEDGE TO RESULTS

KESPTRUM IS THE inventor of Product DNA™, a parameterized, multi-variable, analytical stress-life model that represents an organization's highest level of knowledge about their products (stress, load and load cycles).

DSP generates the Product DNA™ and can be used to perform sensitivity analysis on critical model parameters (e.g. wear rate, aging, etc.), model geometry (e.g. clearance), and System Parameters (e.g. oil degradation) even before creating technical drawings.

GENERATE YOUR PRODUCT'S DNA:

- Understand your product's real-world capabilities and limits by correlating stress-drivers with how and when a product will fail.
- Eliminate recalls and gain a clear understanding of your safety margin, enabling the highest degree of confidence amongst all stakeholders of the organization.



- Build your DNA map, the intelligent center to traceably absorb analytical models and test & field behaviour into one integrated chart.
- Use the DNA map to link your knowledge to results and create a synergy among qualification tests, calculations, stress limit tests, and the analysis of field returns and digital twin data.
- Use our digital twin technology to perform continuous monitoring of your products' field behaviour, correlating the data with the Product DNA in order to calculate RUL (remaining useful life) in real-time.

GENERATE VISIBILITY

WHAT IS DSP?

DNA STRUCTURED PLATFORM

ENGAGE IN A DIGITAL TRANSFORMATION

THE DNA STRUCTURED PLATFORM (**DSP**) is an enterprise-level software that combines our unique engineering methodology, "Method for deterministic stress based risk reduction" (Patent No. US20140081583A1) and our requirement digitization capabilities, "Method of making a Digital Specification" (Patent Pending No. US18/107,075) within a Model-Based Systems Engineering (**MBSE**) environment, in order to generate greater connectivity, traceability, and repeatability within an organization's development processes.

DSP's collaborative platform empowers Advanced Engineering teams to solve complex problems in less than 8 weeks using these three steps:

- **Digital Spec. -** *Finds Non-deterministic Designs*
- **Digital DNA** - *Defines Deterministic Life*
- **Digital Twin** - *Predicts Remaining Useful Life*

DSP is a tool and platform for your company to make the jump to industry 4.0, providing engineers with a collaborative platform to design and qualify complex products against different applications, and embrace Model-Based Engineering practices to reduce costs and achieve stable production.

DSP's Operational Value Propositions:

- Supports new product development from concept to production
- Finds potential random problems and solutions without field data
- Identifies key Model Parameters/Geometry Dimensions impacting performance and life
- Enables important design modifications *before* prototyping
- Reduces development time and cost
- Qualifies new platform technologies
- Supports supply chain and value engineering initiatives to quickly and reliably achieve cost reduction targets and qualify new suppliers
- Provides predictive analytics for product life calculation
- Provides tools for full digital twin realization

THE NEW NORM IN DEVELOPMENT

DSP IN ACTION

A FULLY INTEGRATED DIGITAL PLATFORM

CREATE SYNERGY IN YOUR PLM

DSP IS A COLLABORATIVE engineering platform with a multi-domain approach, based on Model-Based System Engineering (**MBSE**), to replace Diagnostics with Prognostics.

The DSP is a digital transformation tool that:

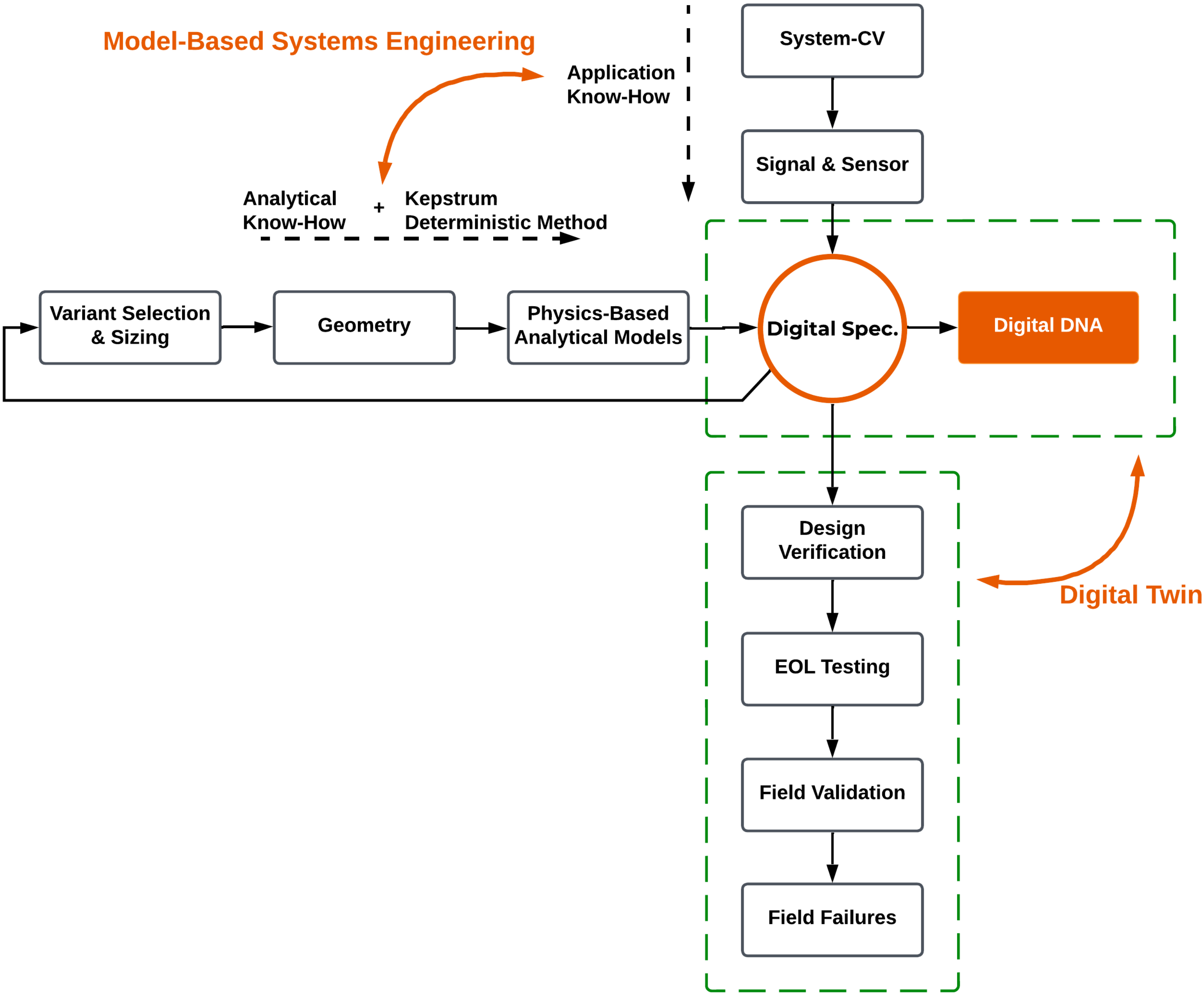
- Embeds reliability into engineering design and analysis.
- Replaces words with profiles, files with maps, PowerPoint with visual documentation, and Excel with signal math.
- Replaces uncorrelated information with a traceable system that generates transparency and connectivity.
- Uses digital specification (**Digital Spec.**) capabilities to capture system states in the format of digital profiles that are accessible to all levels of an organization (sales, application, engineering, test and service) in our database environment.
- Connects the pre-development teams with:
    - Application teams
    - Development teams
    - Test departments
- Enables service issue resolution in less than two weeks.
- Converts lessons learned and experience-based solutions (individuals' understanding) into scalable and re-usable physics-based models (company's asset).
- Allows engineers to generate test protocols from the Digital Spec.
- Includes a test-system configuration module that allows engineering teams to export test protocols directly to test machines in any global facility.
- Allows test data to be imported back into DSP and overlayed on the Digital Spec. profiles to perform analysis.

GENERATE CONNECTIVITY

KEPSTRUM'S DNA STRUCTURED PLATFORM (DSP)

IMPLEMENTATION PROCESS FLOWCHART

DSP IMPLEMENTATION can be summarized in the following flow chart:



(Patent No. US20140081583A1): "Method for Deterministic Stress Based Risk Reduction"

(Patent Pending No. US18/107,075): "Method of Making a Digital Specification"

REDUCE DEVELOPMENT TIME BY 50%

CONVENTIONAL

LASTENHEFT (SOR)

based on a single SOR
"Statement of Operational Requirements"

HIGH COST AND LONG LEAD

HIGH RISK OF MISSING FUNCTIONS

TEST STAND DESIGN

SOR based, leading to many early and costly assumptions

HIGH COST ITERATIONS

DESIGN ITERATION

test/statistical based

FMEA AND/OR SIX SIGMA

statistical based failure ranking

HIGH RISK. MANY 1000 HRS & MISSING INTERACTIONS

TEST PROGRAMS

Criteria: Test-to-Pass (series of long tests)
Setup: Performance/Durability based
Measures: Performance only
Interface: Isolated, non-interactive tests

HIGH RISK. CANNOT SOLVE COMPLEX PROBLEMS

TEST TO PASS

cannot connect to the field failures

TWO YEARS

DNA STRUCTURED PLATFORM

Digital Spec.

Generate an accurate visualization of the product's intended performance and derive component functionalities and key performance factors from system logic.

Product DNA

DESIGN LIMIT NATURE OF FAILURE ACTUAL LIFE

Creating the analytical models to identify the key stresses and fix product weaknesses in the early stages of development. The analytical limits lead to the type and location of instrumentation to set up and calibrate the DNA Generators.

Design Limit Test

All-in-One qualification test including all multi-stress interactions to replicate complex real-world operating conditions and product limits.

Product DNA Library

DSP maps the Product DNA for the development baseline, engineering changes, new suppliers, cost reduction initiatives and production parts to map the DNA Library. Field failures will be captured by the DNA Library to rapidly determine the root cause

ONE YEAR

We give you more time to think ...

Kepstrum's DNA Structured Platform

Tier Ones' Solution for Rapid Alignment With OEMs' No DV Plan

DVP&R BASED SOR

LASTENHEFT (SOR)

Based on a single SOR
"Statement of Operational Requirements"

HIGH COST AND LONG LEAD

HIGH RISK OF MISSING FUNCTIONS

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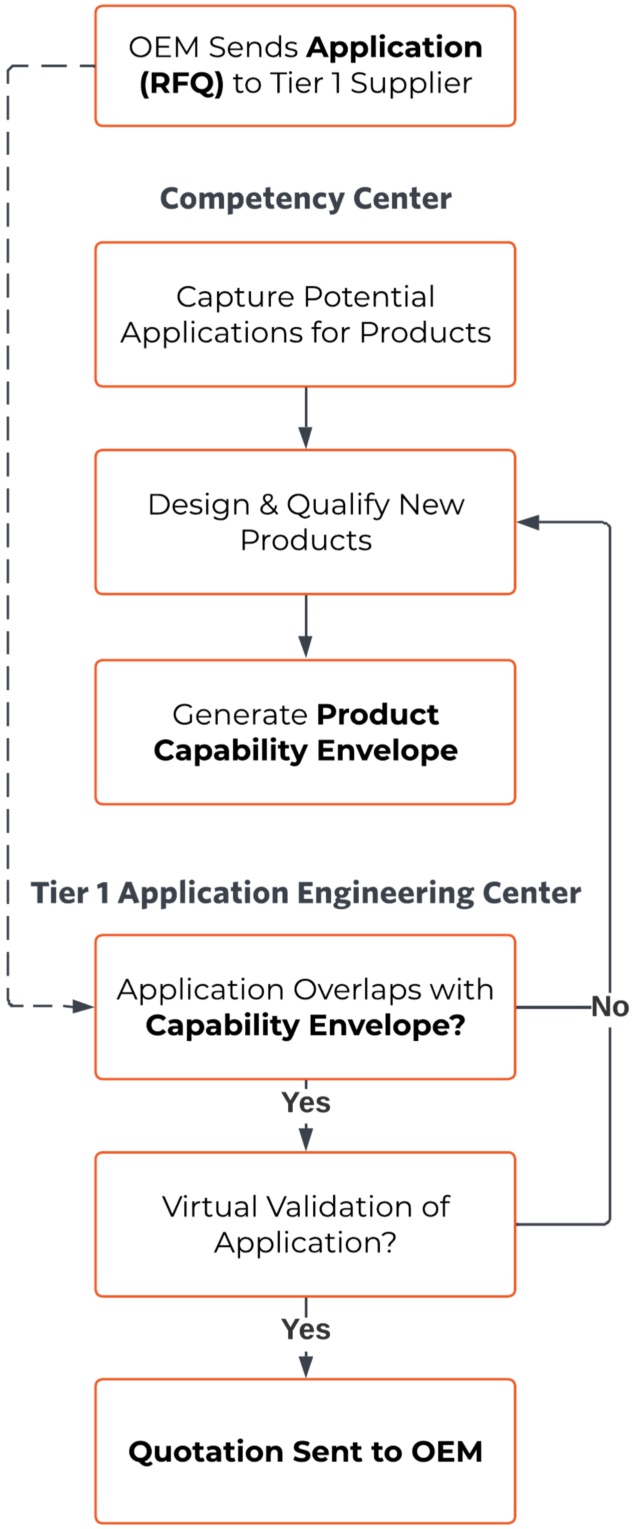
HIGH RISK. CANNOT SOLVE COMPLEX PROBLEMS

TEST TO PASS

cannot connect to the field failures

2 Years to Field Testing

APPLICATION BASED SOR (No-DV)



Qualified Component
Readily Available
For Field Testing

WHAT IS MBSE?

MODEL-BASED SYSTEMS ENGINEERING

ESCAPE FILE-BASED PROJECT DELIVERY

MODEL-BASED SYSTEMS ENGINEERING (**MBSE**) is a "methodology that uses models as the center of system design, as opposed to document-centric engineering. It supports the requirements, design, analysis, verification, and validation associated with the development of complex systems."[1]

MBSE replaces the traditional file-exchange and external communication structures of project delivery with a centralized digital platform where engineering teams and all relevant stakeholders are able to access, manage, and collaboratively work on a single, consistent, and integrated digital representation of a product.

A MBSE platform is meant to be the primary communication and data management platform that enables an organization to create and manage a single **digital thread** that "connects traditionally siloed elements in manufacturing processes..." to provide "an integrated view of an asset throughout the manufacturing and product lifecycle"[2] and a complete, end-to-end record of a system's development, including design decisions, requirements, testing results, and changes made over time.

Adopting a Model-Based Systems Engineering (MBSE) platform and creating a Digital Thread can provide a number of business benefits, including:

- Improved communication and co-ordination among and within teams
- Increased efficiency and and minimized errors in the development process
- Enhanced traceability to ensure accountability
- Enhanced visibility to faciliate complex problem-solving
- Improved access to data to drive informed decision-making
- Increased reusability of previous work, assets, and experience
- 2-3 times faster completion of projects
- Up to 55% reduction in development costs
- Improved market competitiveness

1. Shevchenko, Nataliya. "An Introduction to Model-Based Systems Engineering (MBSE)." Carnegie Mellon University, Software Engineering Institute's Insights (blog). Carnegie Mellon's Software Engineering Institute, December 21, 2020. http://insights.sei.cmu.edu/blog/introduction-model-based-systems-engineering-mbse/. Accessed 29 Jan 2023
2. Diann, Daniel "Definition: Digital Thread" https://www.techtarget.com/searcherp/definition/digital-thread. Accessed 29 Jan 2023.

INTELLIGENT RELIABILITY

ENHANCE MBSE WITH IRM

ELIMINATE RECALLS & REDUCE REWORK

KESPTRUM'S DSP empowers an organization to capture all the benefits of adopting the MBSE methodology while also embedding an explicit focus on reliability into the organization's engineering design and manufacturing processes.

The DSP goes further than typical MBSE platforms in that it facilitates the computer aided-implementation of our patented "Method for deterministic stress based risk reduction", named Intelligent Reliability Methodology (**IRM**) (Patent No. US20140081583A1), and uses physics-based analytical models as the basis of the digital threads and the system models that represent products in development or production.

IRM AT A GLANCE

IRM IS A SYSTEMATIC AND KNOWLEDGE-BASED process to predict the product life for a specific environment. It uses Multi-Stress/Failure Mechanism interaction analysis techniques to reveal product weaknesses and suggests design solutions in the early stages of development and prototyping.

The guided implementation of this risk reduction methodology within DSP is focused on protecting new products and platforms against recalls and undefined field failures by facilitating the creation of deterministic designs, quantifying design uncertainties and placing physics-based models at the core of the digital threads and system models that are used to represent products.

For existing field issues, IRM uses the same tools to replicate problems and generate multiple design options to resolve them. By providing the ability to map failure modes to failure mechanisms and related stresses, IRM enables organizations to generate "lessons learned" quickly, enabling them to resolve complex issues in a fraction of time and cost of conventional methods.

EMBED RELIABILITY INTO DEVELOPMENT

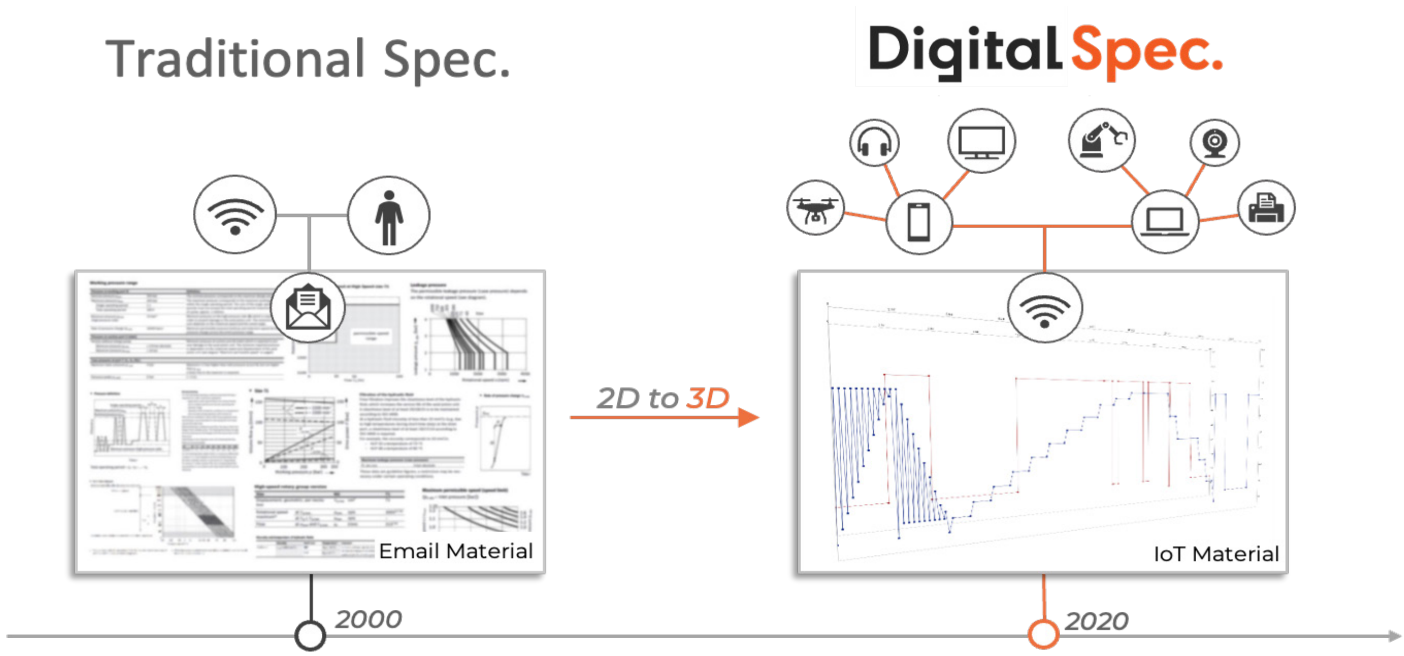
DIGITAL SPEC.

THE FOUNDATION OF DSP'S DIGITAL THREAD

REPLACE WORDS WITH FUNCTIONAL PROFILES

DSP'S MODEL-BASED architecture starts with creating a product's Digital Specification, or **Digital Spec.** (Patent pending: US 18/107,075), our tool for converting traditional product specification and requirements into digitized functional profiles made of signals.

A Digital Spec. functional profile is the starting point for creating a comprehensive and integrated representation of a product as it progresses from the concept stage to a physical product and enables engineering teams to eliminate the ambiguity and complexity of capturing complex product requirements in wordy uncorrelated documents and emails.



IN ORDER TO ALLOW for a seamless transition from conventional development processes to Kepstrum's Digital Spec., engineering teams can import product specification and requirement documents into DSP, through any applicable format (CSV, XLSX, PDF). The engineers can then parse, tag and convert such documents into an accurate visualization of the product's intended performance.

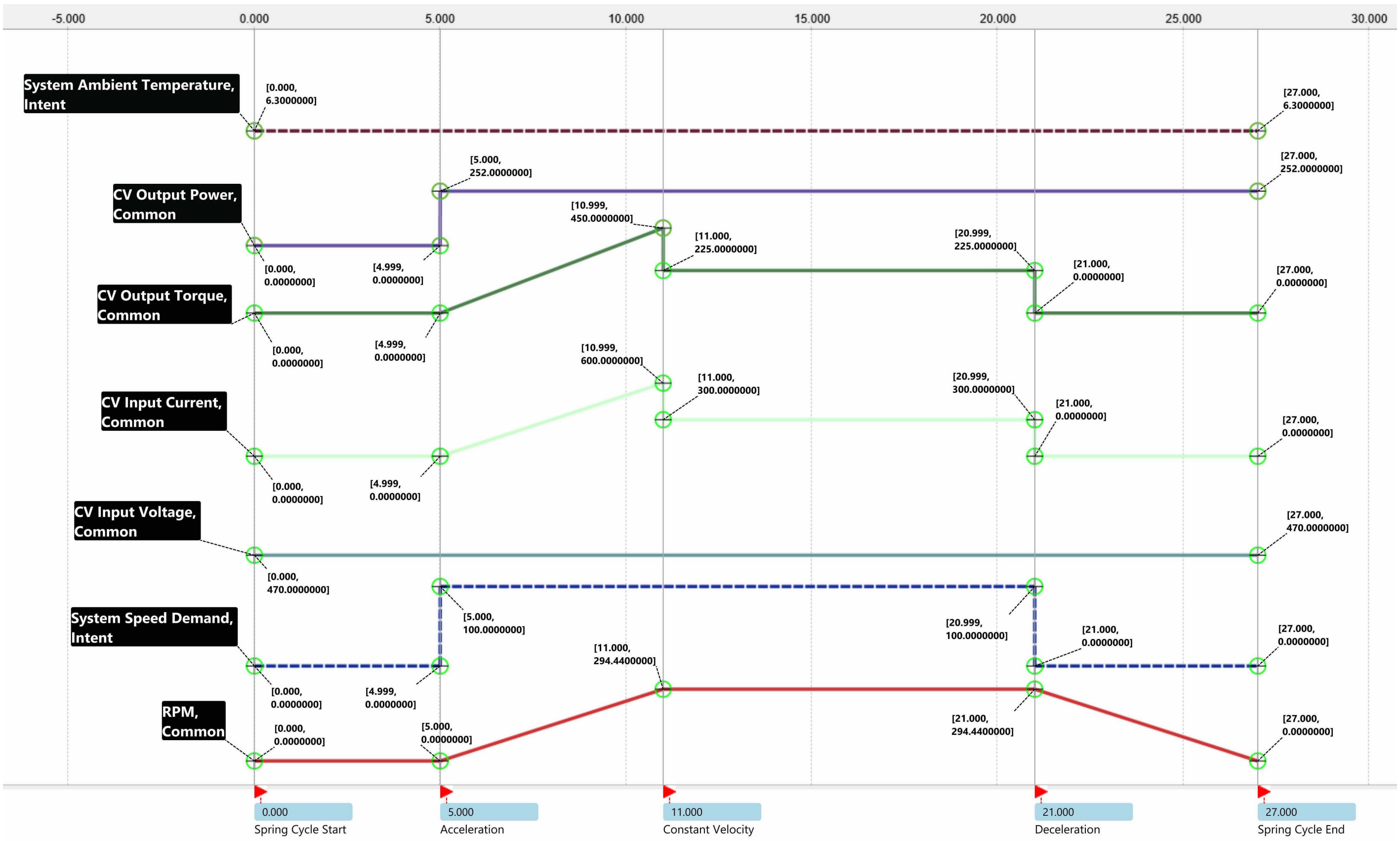
ACCURATELY VISUALIZE PRODUCT FUNCTIONS

DIGITAL SPEC.

INTEGRATING SPEC. AND PERFOMANCE DATA

VALIDATE PERFORMANCE AGAINST REQUIREMENTS

WITH A COMPLETE DIGITAL SPEC. functional profile, your engineers can accurately understand a product's performance in real-world operation, and easily compare and relate the product's projected behavior against the requirements in a single graphical interface.



DIGITAL SPEC. PROFILE OF A PERMANENT MAGNET SYNCHRONOUS MOTOR (PMSM) FOR AN ELECTRIC VEHICLE APPLICATION

SALES AND APPLICATIONS TEAMS can overlay customer requirements on existing Digital Spec. profiles to respond to Request for Proposals (**RfP**) more efficiently, enabling the organization to seek and evaluate new application markets for their products with speed and confidence, ultimately generating new revenue streams.

UNDERSTAND REAL-WORLD PERFORMANCE

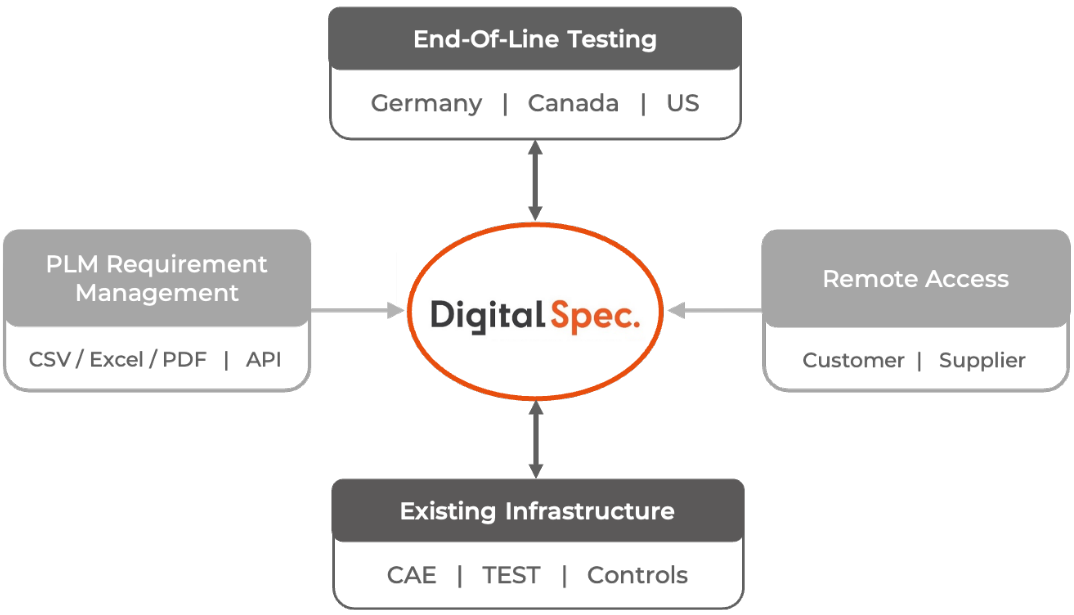
DIGITAL SPEC.

CONNECTING ALL LEVELS OF DEVELOPMENT

MAKE YOUR DATA FUNCTIONAL

THE TERM "FUNCTIONAL PROFILE" indicates that the data represented therein is fully integrated with the DSP's other functions:

- Digital Spec. functional profiles can be used as inputs to DSP's signal-mathematics for sizing calculations and generating parameterized stress-life models (Product DNA), while individual signals can be used to calculate other signals.
- Digital Spec. functional profiles can be used in DSP to generate test protocols that can be directly exported to test machines in any global facility. Test data can then be imported and compared against these profiles for correlation and validation.
- Digital Spec. functional profiles can also be integrated with existing infrastructure (e.g., using CAE as a virtual test bench to validate results) to empower simulation teams to focus on optimization and design verification.



FOSTER FULL PLM INTEGRATION

WHAT IS DIGITAL TWIN?

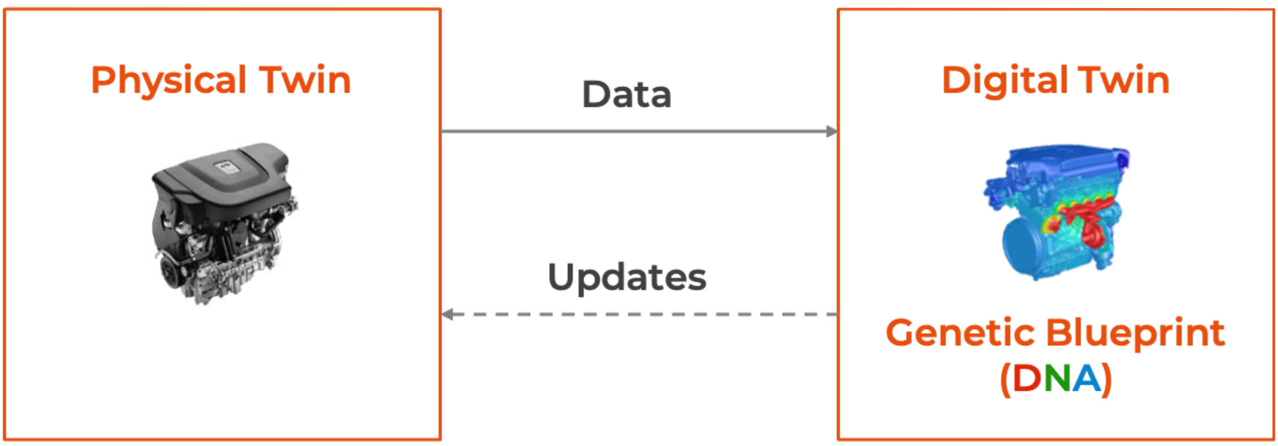
REAL-TIME MODEL-BASED PROGNOSTICS

MONITOR & PREDICT A PRODUCT'S FIELD BEHAVIOR

DIGITAL TWIN TECHNOLOGIES build on the foundations of MBSE and digital threads to create virtual representations of physical products that are integrated with real-time data from the field.

Digital twins monitor the behavior of the product in order to allow for predictive maintenance, design validation, and optimization of the asset.

With digital twin technology, organizations can manage their products in the field by calculating their Remaining Useful Life (**RUL**), implementing state-of-health (**SoH**) alerts to OEMs and their customers, and scheduling product maintenance and replacement before field failures or reaching a desired minimum RUL threshold.



CONNECT DEVELOPMENT TO THE FIELD

PRODUCT DNA

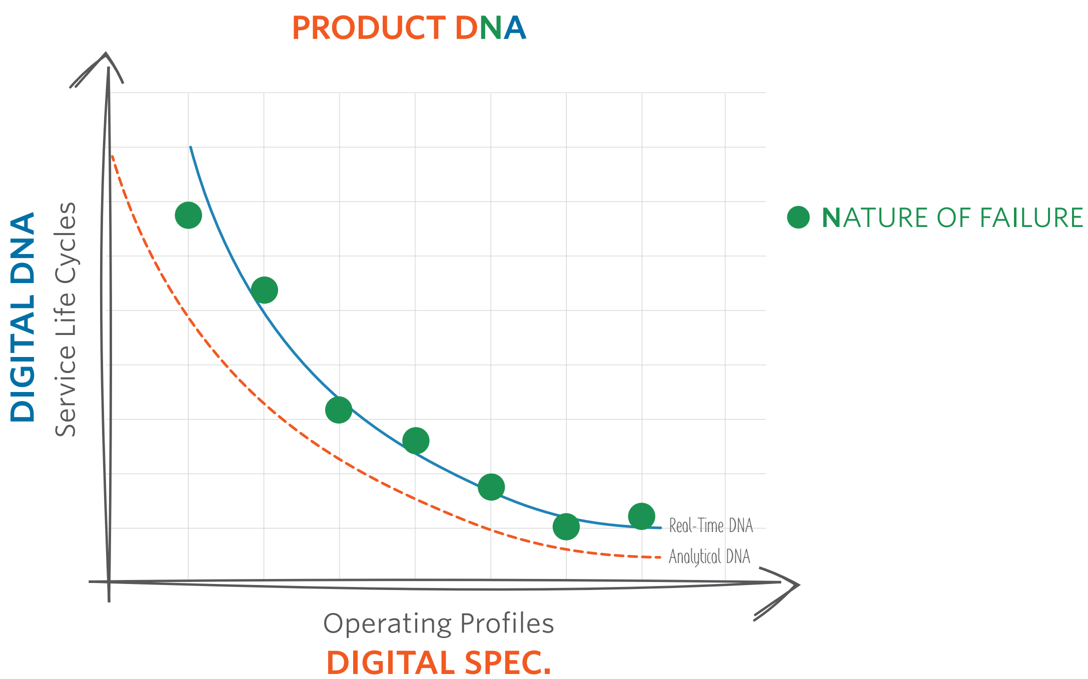
A UNIQUE IDENTIFIER

FIND FIELD FAILURES BEFORE PRODUCTION

PRODUCT DNA is a deterministic, repeatable and traceable reliability measure. It correlates the Stress-Drivers with how and when the Product will fail.

DESIGN LIMIT:	Stress limit correlated with a Stress-Driver (x-axis)
NATURE OF FAILURE:	Failure mechanism correlating the limit and life (map)
ACTUAL LIFE:	Time to failure correlated with a Stress-Driver (y-axis)

Product DNA replaces the conventional test-to-pass with test-to-map replicating field failures to find product weaknesses and provide design solutions. Product DNA controls risk by reducing field failures significantly.



AN IMPACT ON MODERN RELIABILITY

DNA LIBRARY

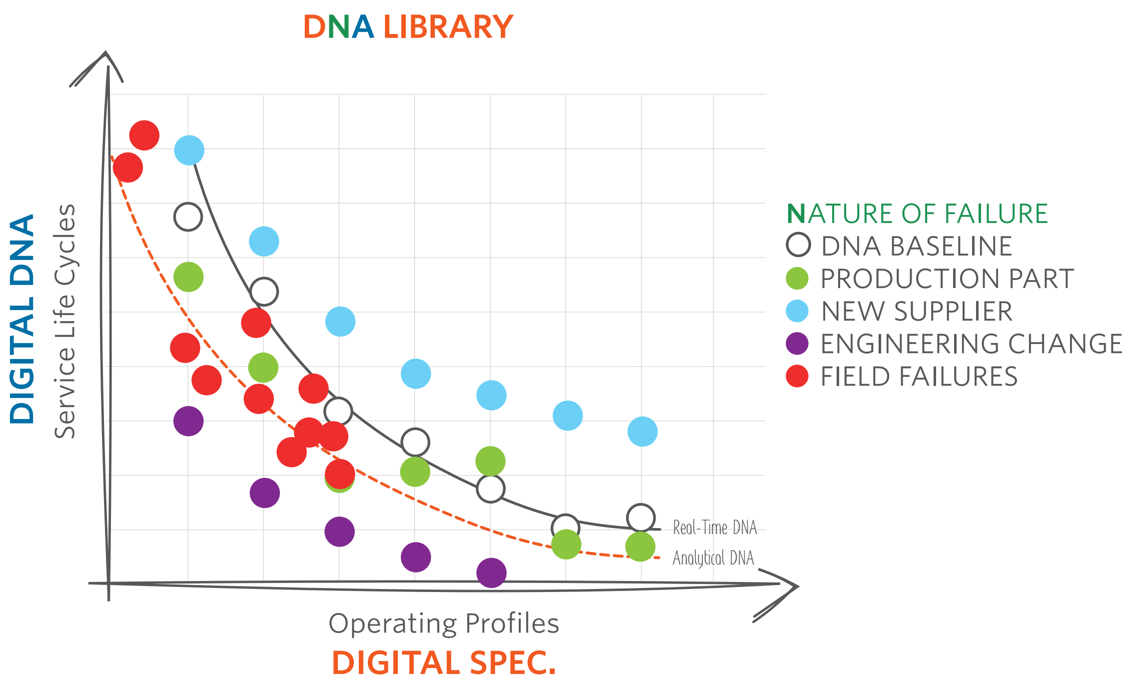
CONTROLLING RISK IN GLOBAL DEVELOPMENT

SOLVE COMPLEX PROBLEMS

PRODUCT DNA connects development and production information to field failures. It provides the global development, application and production sites with a common reliability indicator to control risk.

KXC generates the Product DNA for the development baseline, new suppliers, engineering changes and production parts. They are mapped together to produce the **DNA LIBRARY**.

Field failures will be compared with the DNA Library to determine the root cause rapidly. The DNA Library provides a deterministic solution to solve complex problems systematically, eliminating trial and error.



CONNECTING MANAGEMENT TO THE BIG PICTURE

MAP YOUR PRODUCT DNA™

DESIGN LIMIT NATURE OF FAILURE ACTUAL LIFE

5 STEPS

ONE POWERFUL INDEX

5 STEPS

ONE POWERFUL INDEX ...

MAP PRODUCT DNA TO PREVENT RECALLS

STEP 1: Map your Design DNA
STEP 2: Map your Production Parts
STEP 3: Map your Design Changes
STEP 4: Map your Field Failures
STEP 5: Map your DNA Library

DSP
A COMMON PLATFORM FOR ALL STEPS

DSP maps the Product DNA through critical stages of development and production in 5 patented steps. It generates an intelligent DNA Library that connects the engineering teams to field failures.

Benefits:

- Eliminates the need for multiple test benches
- Connects OEMs and suppliers through a unique reliability measure
- Generates a traceable reference point for future designs
- Keeps development and production sites connected and in control
- Reduces field failures by finding product weaknesses in development
- Solves complex problems through simultaneous stress interactions
- Shortens the development time
- Reduces the development cost
- Controls risk to prevent recalls

MAXIMIZING YOUR PROFITABILITY

STEP 1

MAP YOUR DESIGN DNA

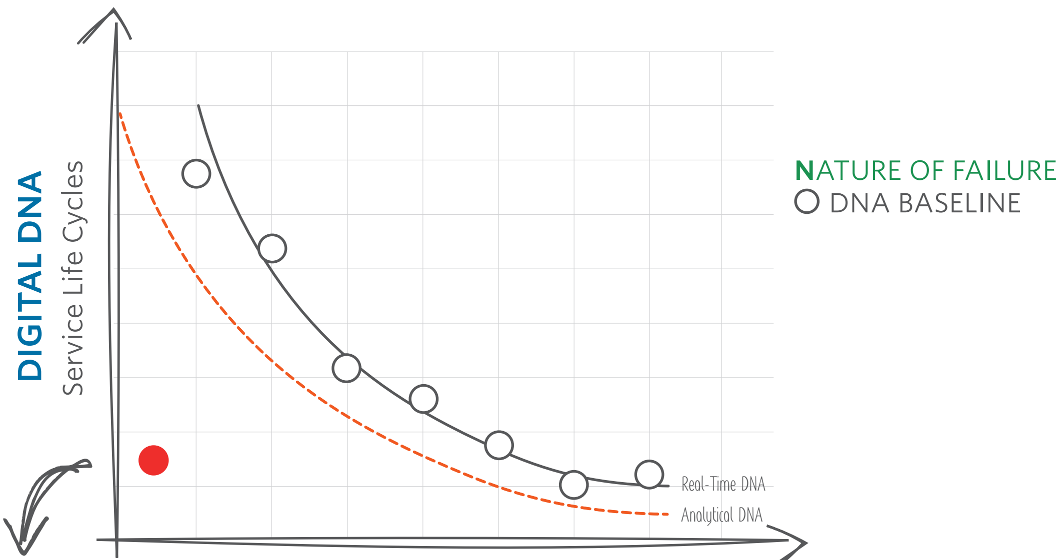
CREATE A DESIGN BASELINE

Map and modify your Product DNA to reach the design baseline with the desired service life. Use the DNA Baseline to check production quality, validate changes and connect to field failures. Analytical baselines are generated from first principles to identify the theoretical limits, failures and life.

Benefits:

- Replicate real world complexity
- Derive key stresses
- Reveal product weaknesses
- Replace meaningless test-to-pass with measurable test-to-map
- Replace long term durability tests with a Product DNA Map

PRODUCT DNA BASELINE



Operating Profiles

DIGITAL SPEC.

A Typical 1000-hour durability test:

1. Is far from the Product DNA Map
2. Does not qualify the service life
3. What if the test failed in the 800th hour? Redesign?

STEP **2**

MAP YOUR PRODUCTION PARTS

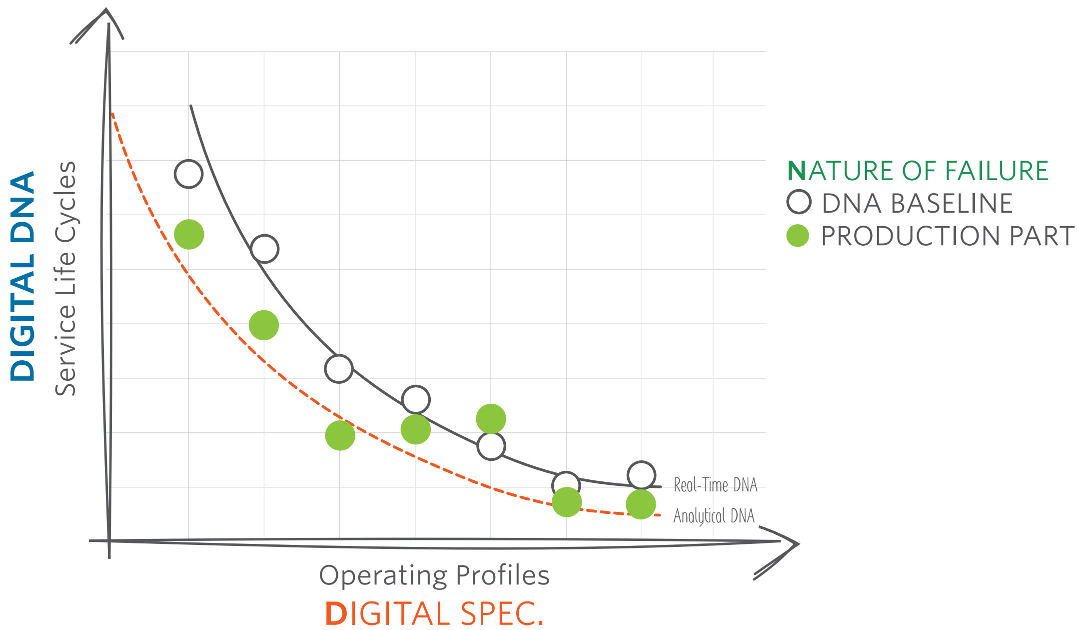
STRESS PRODUCTION BATCHES

Compare the Product DNA Baseline with production batches to regularly verify your output quality.

Benefits:

- Monitor production variations over the entire stress spectrum
- Compare production part failures with the DNA Baseline
- Correlate with the analytical maps

PRODUCTION MAP



STEP **3**

MAP YOUR DESIGN CHANGES

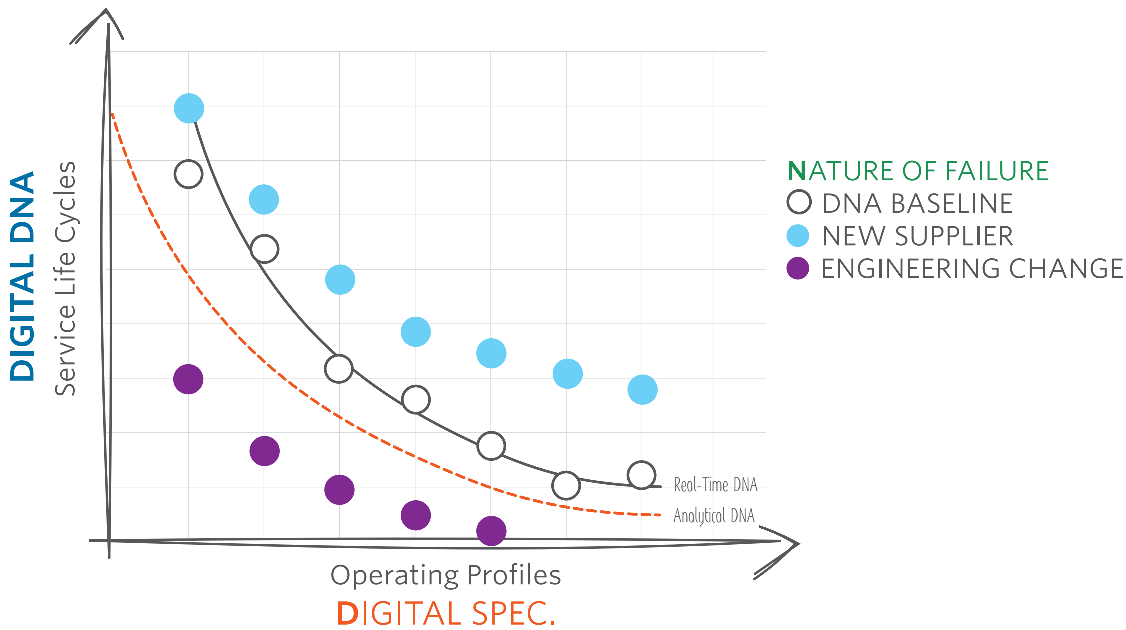
STRESS ALTERNATIVE DESIGNS

Compare the Product DNA Baseline with alternative designs to verify cost reduction changes and support continuous improvement initiatives.

Benefits:

- Validate the design changes and alternative suppliers
- Compare failures for new prototypes with the DNA Baseline
- Correlate with the analytical maps

DESIGN VALIDATION MAP



STEP 4

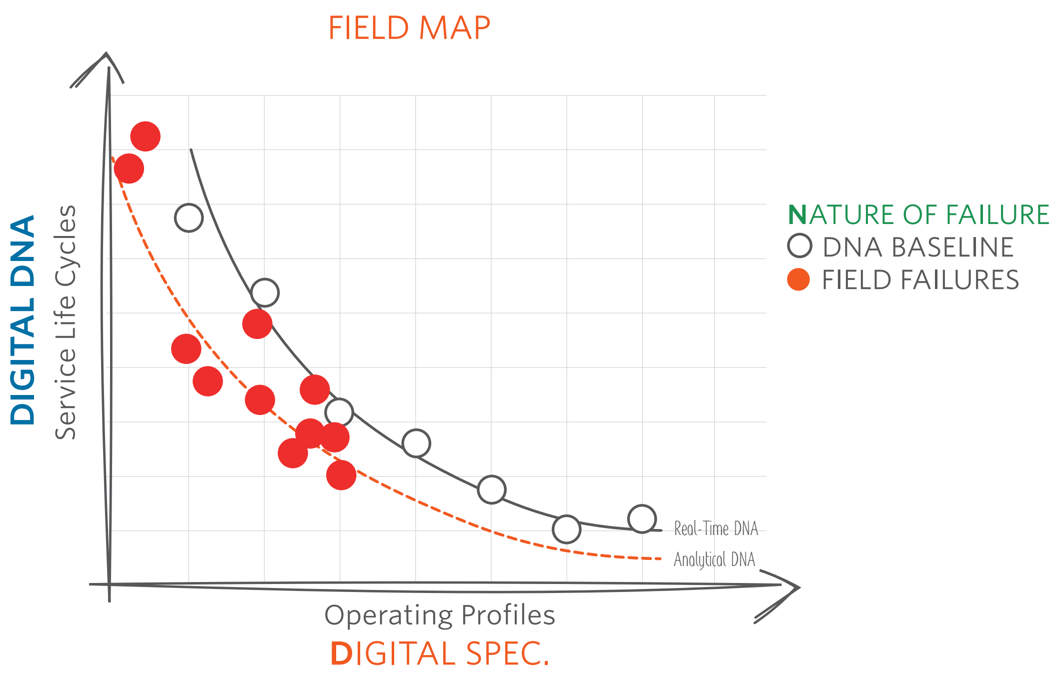
MAP YOUR FIELD FAILURES

CONNECT DEVELOPMENT TO FIELD

Map the field failures with your Product DNA Baseline to correlate with development, identify root-causes and refine your database. Demand Product DNA for purchased components from current and alternative suppliers, as controls to meet your reliability goals.

Benefits:

- Close the loop between development knowledge and field information
- Compare in-service failure mechanisms with the DNA Baseline
- Solve complex field problems rapidly and systematically



STEP 5

MAP YOUR DNA LIBRARY

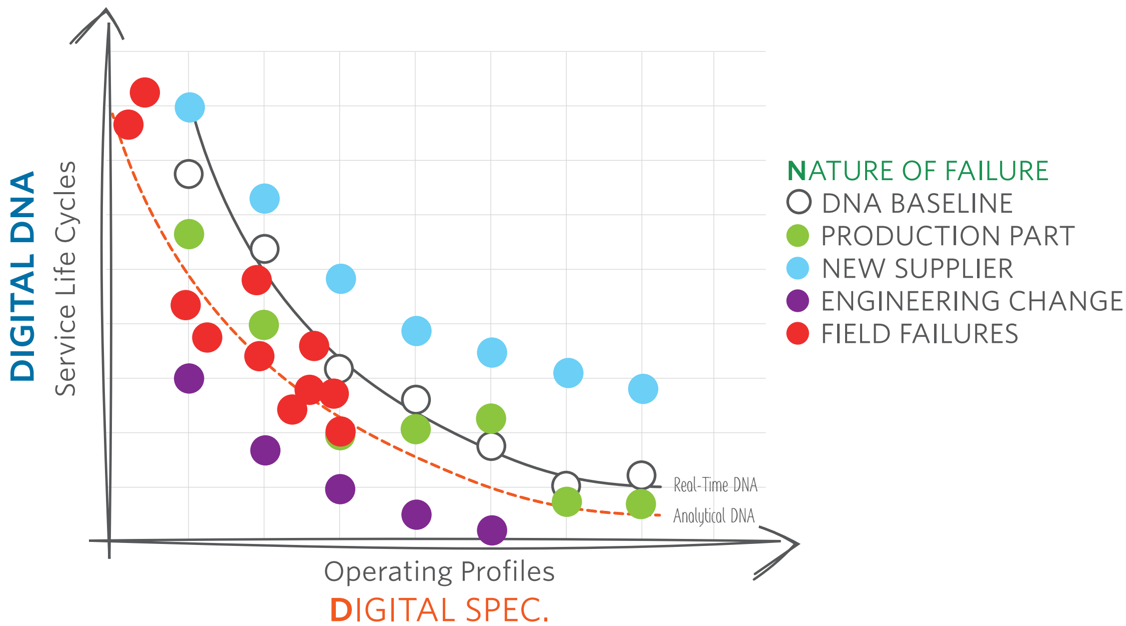
CREATE AN ACCURATE VIEW

Product DNA is an intelligent library, containing all you need to know about your product, its revisions, design limits, failure mechanisms and service life expectancy. The DNA library creates an accurate view of product behaviour, supporting design innovation to maintain market leadership.

Benefits:

- A repeatable benchmark from research to production
- A traceable reliability measure between OEMs and suppliers
- A new norm and approach to generate SORs (statement of operational requirements) and LASTENHEFTE
- Creating an effortless decision making process
- Keeping management well informed and in control

AN INTELLIGENT MAP



Kepstrum

CUSTOMER TESTIMONIALS

CUSTOMER TESTIMONIALS

See what our collaborators have to say about Kepstrum's results

BOSCH GERMANY
HERBERT REDER,
ENGINEERING LEAD - CENTER OF VALVE COMPETENCY

"Intelligent Reliability Technology offers repeatability, speed and accountability to generate results and knowledge utilizing our capabilities"

STACKPOLE INTERNATIONAL
RICHARD MUIZELAAR,
DIRECTOR OF RESEARCH AND INNOVATION

"With Kepstrum DSP software and engineering methodology, our confidence is greatly enhanced in understanding our product in application with multi-domain transfer functions of stress and Key Performance. The Kepstrum method enables deterministic definition of our product in application, with transparency, and with breakdowns of the critical interfaces to judge life, wear and performance. Using this information we are able to prioritize and optimize test cycles that ensures the key performance and wear damage correlates to defined first principle models. We are able to accelerate validation testing by combining our deterministic physics based math models, to accelerated stress tests. The power of this approach is the linkage of knowledge and results. Compared to other traditional methodologies, Kepstrum's DSP approach closes the gaps in understanding to questions not normally asked.

Working together with Kepstrum, we were able to identify 'non-deterministic' scenarios and failure modes in a 'single bushing' drive system. We changed the design to a 'double bushing solution' to address several identified failure modes. The improvement was accomplished during the design phase and it has performed well to complete all required testing and validation activities.

We are again excited to utilize Kepstrum's unique engineering methodology and software to now link manufacturing influences with functional performance test sequences to perform physics based life assessments."

"The power of this approach is the linkage of knowledge and results."

BOSCH REXROTH
MARTIN DAUB,
MANAGER OF TESTING / VALIDATION

"Over the past years Kepstrum supported us in several projects on hydraulic pump components to understand lifetime and failure issues.

Kepstrums methodical approach gives a comprehensive overview of non-deterministic critical design features in a very early concept phase of engineering work. It helps to lead the engineering process straight forward, minimizing design iterations.

The DNA structured platform has the potential to integrate knowledge of multiple teams and functions into one platform to enhance collaboration along the engineering process.

The methods and tools are continuously refined and improved by Kepstrum."

"Über die letzten Jahre hat uns Kepstrum in mehreren Projekten bzgl. Lebensdauerthemen und Ausfällen an Komponenten für Hydraulikpumpen unterstütz.

Kepstrums methodischer Ansatz gibt einen umfassenden Überblick, über die nicht deterministischen kritischen Design Merkmale in einer sehr früher Konzept Phase. Dies unterstützt den Entwicklungsprozess und reduziert Schleifen. Die „DNA structure platform" (DSP) bietet die Möglichkeit das Wissen von mehreren Teams und Funktionen in eine Plattform zu integrieren um die Zusammenarbeit entlang des Produktentstehungsprozess zu verbessern.

Die Methoden und Tools werden von Kepstrum kontinuierlich weiterentwickelt und optimiert."

"The DNA structured platform has the potential to integrate knowledge of multiple teams and functions into one platform to enhance collaboration along the engineering process."

MAGNA POWERTRAIN
FRITZ ATSCHREITER,

ENGINEERING TEAM LEADER - ADVANCED & ACQUISITION, TECHNICAL SPECIALIST - THERMAL MANAGEMENT AND COOLING

"In meiner Funktion als Leiter der Vorentwicklungs- und Aquisitionsgruppe bei Magna am Standort St. Valentin bin ich seit mehr als zwei Jahr in regelmäßigem Kontakt mit der Firma Kepstrum und konnte auch schon mehrere Projekte mit Payman und seinen Kollegen abarbeiten. Payman Kianpour hat mich ersucht ob ich meine Erfahrungen mit Kepstrum`s Intelligent Reliability Technology (IRT) mit Ihnen teilen könnte. Aufgrund meiner guten Erfahrungen komme ich dieser Bitte gerne nach.

Die Technologie hat sich in einer Vielzahl unterschiedlicher Themenbereiche sehr gut bewährt, ob es um „Troubleshooting" oder Krisenmanagement in den verschiedensten Produktgruppen oder die grundsätzliche zielgerichtete und systematische Entwicklung neuer Produkte geht. IRT ist sehr gut geeignet vorerst nicht ermittelbare Feldausfälle zu klären und damit hohe Schadenersatzforderungen für Magna abzuwenden, des Weiteren wird es sehr erfolgreich eingesetzt um die Kernthemen und Versuche zu definieren um die Entwicklung von neuen und innovativen Produkten voranzutreiben.

Intelligent Reliability bietet den logischen Ansatz für die Unterstützung bei der Entwicklung zuverlässiger Produkte und um die kritischen Merkmale gezielt anzusprechen. Damit ist gewährleistet dass Risiken in einem sehr frühen Stadium erkannt und damit vermieden werden.

Magna wird auch weiterhin mit Kepstrum und IRT in den verschiedensten Projekten zusammenarbeiten."

"Intelligent Reliability bietet den logischen Ansatz für die Unterstützung bei der Entwicklung zuverlässiger Produkte und um die kritischen Merkmale gezielt anzusprechen."

PUBLICATIONS

WHITE PAPERS & BROCHURES

INTELLIGENT RELIABILITY

Kepstrum

Solve complex problems in less than 8 weeks using DNA Technology
Optimize product cost & reliability with speed and depth

ABOUT KEPSTRUM

Kepstrum is the inventor of Product DNA and the Intelligent Reliability Risk Reduction Methodology (IRM), designed to qualify new developments without history. Kepstrum's core competency is in dynamics, fluid power and controls, applying IRM to Engine and Vehicle Electrification with extensive multi-physics libraries in electro-hydraulics, mechatronics, electronics, drives and controls.

ABOUT KEPSTRUM'S DSP (DNA STRUCTURED PLATFORM)

DSP is the computer-aided engineering implementation of IRM. A collaborative platform, empowering the Advanced Engineering Teams to solve complex problems in less than 8 weeks with the following steps:

- **Digital Spec.**
  Finds Non-deterministic Designs
- **Digital DNA**
  Defines Deterministic Life
- **Digital Twin**
  Predicts Remaining Useful Life

Product DNA
Design Limit, **N**ature of Failure, **A**ctual Life
Model Based Prognostics
A Paradigm Shift in Modern Reliability

DSP's Operational Value Propositions:

- Supports new product development from concept to production
- Finds potential random problems with solutions without field data
- Identifies key Model Parameters/Geometry Dimensions impacting performance and life
- Enables important design modifications before prototyping
- Provides predictive analytics for life and Digital Twin realization (production & field)
- Reduces development time and cost
- Qualifies new platform technologies
- Supports supply chain and value engineering initiatives to quickly and reliably achieve cost reduction targets and qualify new suppliers

DSP's Technical Value Propositions:

- Eliminates reliance on e-mail and file transfers using a unique database platform
- Generate and export test protocols directly to test machines in any global facility
- Includes tools for agile project management

KEPSTRUM PLATFORM SUPPORT

Kepstrum continuously performs fundamental research in physics based models to provide unlimited engineering and software support, enabling clients to achieve the Digital Transformation (IoT & Industry 4.0) from experience-based to model-based Design.

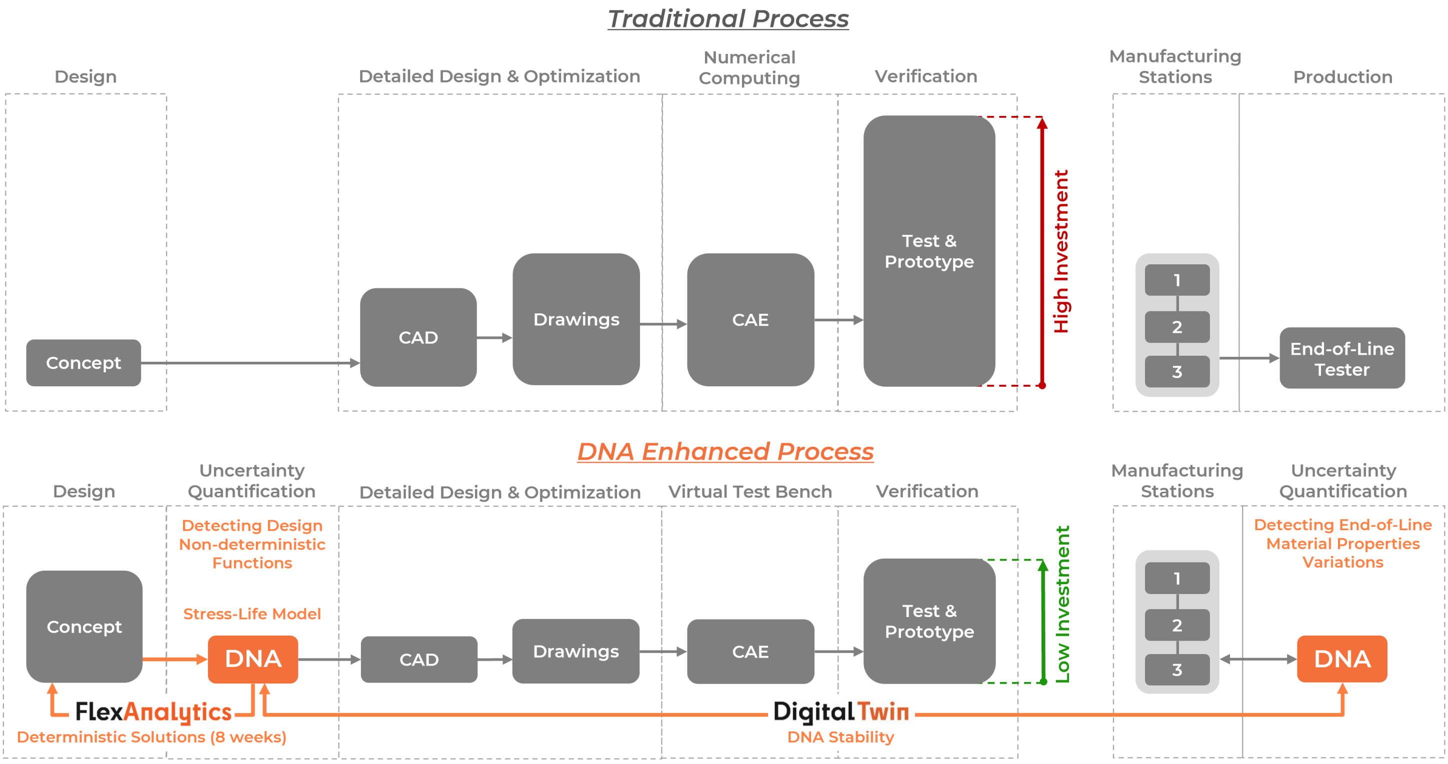
INTELLIGENT RELIABILITY

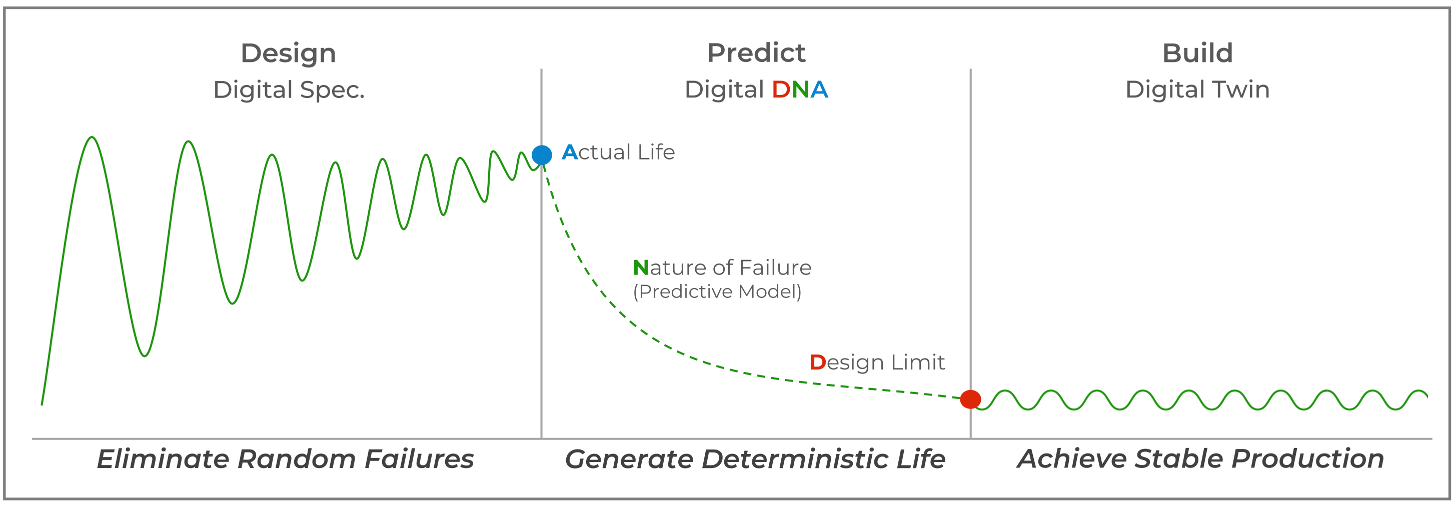
Solve complex problems in less than 8 weeks using DNA Technology
Optimize product cost & reliability with speed and depth

"We must catch Random Problems before Dimensioning the Drawings."

- Payman Kianpour, *Inventor of Intelligent Reliability and Chief Technical Officer, Kepstrum Inc.*

In next generation manufacturing, DNA will calculate the life and CAE will be the virtual test bench. These two scientific computing tools must converge to decide what tests are actually needed.





WHITE PAPERS

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CUTTING COSTS THROUGH DIGITALIZATION
ENHANCING THE POWER OF MBSE WITH THE DSP

The business landscape has undergone a dramatic change due to the impact of technology on internal processes, production methods, and customer connections. In today's highly competitive market, digitalization is crucial for success, especially in the manufacturing and product development industries where new technologies are being rapidly developed to meet evolving and previously non-existent or non-ubiquitous market demands such as electrification. To truly keep pace with rapidly changing market demands and regulations, engineering companies must not only adapt their business platforms but also their engineering methodologies.

To achieve reliable results in technology developments with limited historical data and to eliminate the risk and high financial and reputational costs of unforeseen product failures, a shift to physics-based deterministic development processes must accompany the necessary shift to using digital platforms. This is where Kepstrum's DNA Structured Platform (**DSP**) comes in, an enterprise-level database software that combines the best aspects of Model-Based Systems Engineering (**MBSE**) with physics-based modeling and Kepstrum's patented risk reduction methodology, named Intelligent Reliability Methodology (**IRM**) US 9,612,933, allowing organizations to take advantage of the benefits offered by digital platforms while ensuring the quality and reliability of their products.

Engaging a Comprehensive Digital Transformation With MBSE

A digital transformation can be said to be successful if it manages to increase an organization's collaborative capability (connectivity), their processes' transparency and traceability, product reliability, manufacturing consistency, market adaptability, and reduce procedural and material waste. Any one of these facets of a business's operation can be improved with various enterprise resource planning (ERP) systems, methods, and platforms, but for engineering companies to make a robust and enduring digital ecosystem, these benefits should be pursued simultaneously within a Model-Based Systems Engineering platform; "MBSE is a formalized methodology that uses models as the center of system design, as opposed to document-centric engineering. It supports the requirements, design, analysis, verification, and validation associated with the development of complex systems."[1] MBSE enables an organization to create and manage a single digital thread, "a data-driven architecture that links together information generated from across the product lifecycle and is envisioned to be the primary or authoritative data and communication platform for a company's products at any instance of time"[2]. A digital thread "connects traditionally siloed elements in manufacturing processes and provides an integrated view of an asset throughout the manufacturing and product lifecycle."[3]

Adopting a Model-Based Systems Engineering (MBSE) platform and creating a Digital Thread can provide a number of business benefits, including:

- **Improved Collaboration:** MBSE platforms enable stakeholders to access and collaborate on a single, consistent digital representation of the system, which can lead to improved communication and coordination among team members.
- **Increased Efficiency:** MBSE's centralized structure can streamline the systems engineering process by minimizing errors and inconsistencies that arise from "broken telephones" in the design process.
- **Enhanced Traceability:** A Digital Thread provides a complete, end-to-end record of a system's development, including design decisions, requirements, testing results, and changes made over time. This can help ensure accountability and facilitate complex problem-solving.
- **Better Decisions:** MBSE platforms provide decision-makers with access to a wealth of data for informed decision-making
- **Improved Reusability:** By capturing and storing information in a digital format, it becomes easier to reuse and repurpose the information for other systems and projects, saving time and resources.

Quantifying the savings that can be achieved by switching to MBSE development and production processes can be hard

1. Shevchenko, Nataliya. "An Introduction to Model-Based Systems Engineering (MBSE)." Carnegie Mellon University, Software Engineering Institute's Insights (blog). Carnegie Mellon's Software Engineering Institute, December 21, 2020. http://insights.sei.cmu.edu/blog/introduction-model-based-systems-engineering-mbse/. Accessed 29 Jan 2023
2. Singh, Victor, and K. E. Willcox. "Engineering Design with Digital Thread." AIAA Journal, vol. Volume 56, no. Number 11, 2018, pp. 4515-4528. Aerospace Research Central, https://arc.aiaa.org/doi/10.2514/1.J057255. Accessed 31 Jan 2023.
3. Diann, Daniel "Definition: Digital Thread" https://www.techtarget.com/searcherp/definition/digital-thread. Accessed 29 Jan 2023.

given the variation between and within different industries, but in 2015, Embedded Market Forecasters (EMF) published the results of 6 years of survey data[4] wherein they established that the "addition of model-based systems engineering delivers a 55% reduction in total development cost", and that "MBSE developments have not only proved to be less costly but have continued to cost less as experience with MBSE has increased." The ROI of MBSE only compounds as organizations fully adopt the system and move from modeling individual products to entire product lines. The increasing ability to re-use assets and knowledge in a mature MBSE environment only enhances the benefits.

EMF also acknowledged that MBSE enables faster development times with fewer development delays, using smaller, more effective and more connected engineering teams. The inherent benefits of such a system mean that projects aren't just completed 2-3x faster than similar endeavors pursued within the context of traditional development cycles, they are also delivered at a higher quality that is closer to the pre-design expectations that were outlined in the product and system requirements.[5]

Organizations that employ MBSE systems in their production methods are not just more cost effective, they are more competitive; they can more easily respond to time-sensitive market opportunities, old assets can be easily upgraded, and disconnected knowledge and experience can be leveraged to meet those opportunities. The increase in productivity and savings may be variable but are nonetheless undeniable; scaled to an organization's individual circumstances, with factors such as product complexity, production volume, and other project-specific elements influencing the potential savings a MBSE infrastructure can deliver.

Enhancing MBSE with a Focus on Reliability

The benefits of engaging a digital transformation with MBSE are clear, but the increases to product reliability are a by-product of improved collaboration and traceability. Kepstrum's DSP enables an organization to capture all the benefits of creating a digital thread in a robust MBSE platform while also embedding an explicit focus on reliability into the organization's engineering design and manufacturing processes. The DSP facilitates the computer-aided implementation of Kepstrum's U.S. Patented Intelligent Reliability Methodology (IRM). The guided implementation of this risk reduction methodology within the DSP is focused on protecting new products and platforms against recalls and undefined field failures by facilitating the creation of deterministic designs and placing physics-based models at the core of the digital threads and system models that are used to represent products.

IRM further compounds the savings that can be achieved with MBSE platforms by revealing design weaknesses before physical prototyping, and quantifying design uncertainties. The time and economic costs of re-work, re-designing, producing and re-testing components, can almost be entirely eliminated. Furthermore, using algorithms derived from Kepstrum's deterministic analysis, traditional test-to-pass testing can be replaced with design limit testing that enables organizations to reduce development testing significantly, while simultaneously empowering end-of-line tests to identify material variation in half the time of conventional testing.

The Importance Of Physics-Based Modelling in Engineering & Manufacturing Industries

The DSP was designed to help organizations improve their product development processes and reliability by serving as a platform for documenting, managing, and fully integrating physics-based analytical models into their development processes, all in the context of a modernized MBSE platform. In addition to the extensive library of physics models that are accessible to all DSP users, the DSP facilitates the gathering and application of an organization's knowledge and expertise to convert them into physics-based models to help tackle any challenges that the organization's R&D departments may face as they continue to push technological boundaries. The benefits of this physics-based foundation of a digital thread are clear when taking a closer look at another important tool in the modern technological development arsenal: Digital Twins.

4. Krasner, Jerry "How Product Development Organizations Can Achieve Long-Term Cost Savings Using Model-Based Systems Engineering (MBSE) ---How financial managers can achieve lower costs of development, faster deployment of new products, and lower ongoing maintenance costs". October 2015. Docplayer.net https://docplayer.net/18566603-How-product-development-organizations-can-achieve-long-term-costsavings-using-model-based-systems-engineering-mbse.html , Accessed 31 Jan 2023.
5. Carroll, Edward Ralph, and Malins, Robert Joseph. 2016. "Systematic Literature Review: How is Model-Based Systems Engineering Justified?.". United States. https://doi.org/10.2172/1561164. https://www.osti.gov/servlets/purl/1561164. Accessed 2 Feb 2023

CUTTING COSTS THROUGH DIGITALIZATION
ENHANCING THE POWER OF MBSE WITH THE DSP

Digital twins are virtual representations of physical systems or products and are created by integrating real-time data from sensors and other sources with models of the physical asset. The models created in MBSE platforms can be used to create a digital twin, which can then be used to simulate the behavior of the physical asset in real-time, allowing for real-time monitoring, prediction, and optimization of the asset.

Digital twin technologies have a number of values, including:

- **Improved design and testing:** By creating a virtual representation of a physical system, digital twin technology allows for improved design, testing, and optimization of that system before it is built or implemented.
- **Predictive maintenance:** Digital twin technology can be used to monitor and predict the behavior of physical systems, enabling more proactive maintenance and reducing the risk of unexpected failures.
- **Increased operational efficiency:** By providing real-time insights into the performance of physical systems, digital twins can be used to optimize operations and improve efficiency.
- **Better decision-making:** By providing a complete picture of a physical system and its interactions, digital twin technology can support better decision-making by providing a deeper understanding of system behavior.

Digital Twin solutions can increase revenues by "10 percent, accelerate time to market by as much as 50 percent, and improve product quality by up to 25 percent" [6], and are projected to grow 10x in the next five years. Engaging a digital transformation with a digital twin capable foundation is important, but not all digital twins are created equal.

Organizations pursuing digital twin technologies have the option of either using numerical or analytical methods as a foundation for modelling the real world operation of their products. The main difference between these two types of modelling lies in the underlying mathematical models used to represent the system being studied. In the context of traditional engineering development, digital twins are built only using numerical simulations that use mathematical models and algorithms to simulate the system's behavior and solve complex problems. The goal of numerical simulation is to find approximate solutions to these problems by breaking them down into smaller, simpler parts that can be solved computationally. The models are based on assumptions about the system and its behavior, and thus cannot provide exact solutions.

While this method can provide valuable insights and predictions, there are some limitations to consider:

- **Modeling limitations:** Numerical simulations can only provide an approximation of the real-world system. The accuracy of the simulation depends on the accuracy of the mathematical models used, which may not fully capture all of the physical processes involved.
- **Computational cost:** Depending on the complexity of the system being modeled, numerical simulations can be computationally expensive, requiring significant amounts of time and computer resources.
- **Lack of transparency:** Numerical simulations can be complex and difficult to interpret, especially for non-experts. This can make it challenging to understand the underlying physics of the system being modeled, update the underlying models, and validate the results.

On the other hand, in the context of the deterministic development process that the DSP facilitates, digital twins are built by first using predictive models that rely on physical laws and principles to describe the behavior of systems. The predictive models are based on first principles and analytical closed-form equations, to provide a precise representation of the physical behavior of a deterministic system. Engineering teams are able to generate the appropriate models that can explain the behavior of the physical system under a wide range of conditions (flex analytics), without the boundaries of fixed analytics offered by typical simulation packages. The deterministic boundaries and predictive life models generated by the DSP can be fed to simulation teams who can then focus on performance optimization and use their simulations as virtual test benches, allowing these two scientific computing methods to converge to minimize necessary physical testing while increasing reliability.

6. Brossard, Mickael, et al. "Digital Twins: The Art of the Possible in Product Development and Beyond." McKinsey & Company, 30 Nov. 2022 https://www.mckinsey.com/capabilities/operations/our-insights/digital-twins-the-art-of-the-possible-in-product-development-and-beyond , Accessed 29 Jan 2023

CUTTING COSTS THROUGH DIGITALIZATION
ENHANCING THE POWER OF MBSE WITH THE DSP

The Foundation of our Digital Thread: Digital Spec.

The DSP's Model-Based Systems Engineering (MBSE) architecture and digital twin capabilities start with Digital Spec. (Patent pending: US 18/107,075), our tool for converting traditional product specifications and requirements into digitized functional profiles made of signals. A Digital Spec. profile is the comprehensive and integrated representation of a product as it evolves from the concept stage to a physical product and can represent information about the product's functional requirements before being expanded upon to model and visualize the product's complex functions, interactions, and stresses as the design process advances. In true MBSE fashion, Digital Spec. profiles eliminate the ambiguity and complexity of analyzing complex product requirements in wordy, uncorrelated specification documents and emails. The Digital Spec. is the main engine of the DSP, and can be used as direct inputs to other functions within the DSP.

Enhancing MBSE with IRM and Product DNA

Once the product requirements are captured in the Digital Spec., the engineering teams are enabled to make use of Kepstrum's Intelligent Reliability Methodology. As previously mentioned, IRM is broadly used to protect new products and platforms against recalls and undefined field failures. It uses Multi-Stress/Failure Mechanism interaction analysis techniques to reveal product weaknesses and suggests design solutions in the early stages of development and prototyping. IRM is a systematic and knowledge-based process to generate model-based prognostics for any product. Once the Digital Spec. profiles are expanded upon to model a product's internal functions and external interactions, the product's capabilities are determined by using the profiles, and their constituent signals, as direct inputs to the DSP's analytical mathematical computing functions to generate the product's DNA (Design Limit, Nature of Failure, Actual Life).

Product DNA is an index encompassing a comprehensive multi-variable stress-life model that determines the product's true life expectancy and provides a repeatable and traceable reliability measure that correlates stress-drivers with how and when a product will fail. The DNA Map integrates all the elaborated knowledge represented in the product's digital thread and creates a synergy among qualification tests, calculations, stress limit tests and the analysis of field returns and digital twin data, which are all accessible through one database. With this index and understanding of a product's real world capabilities and limits, manufacturers can eliminate recalls and gain a clear understanding of their safety margin, enabling the highest degree of confidence amongst all stakeholders of the organization. For existing field issues, IRM uses the same tools to replicate problems and generate multiple design options to resolve them. By providing the ability to map failure modes to failure mechanisms and related stresses, IRM enables organizations to generate "lessons learned" quickly, enabling them to resolve complex issues in a fraction of time and cost of conventional methods.

Enhance Productivity, Optimize Costs, & Seize Market Opportunities with the DSP

The DSP optimizes product cost and reliability for engineering teams by consistently digitizing product requirements into the integrated Digital Spec. format in order to understand their capabilities in real world operating conditions. By overlaying customer requirements on the product's capability, engineers can quickly respond to customer RfQs (Request for Quotation), thus empowering the engineering teams to continuously seek new market opportunities for their products. The MBSE architecture of the DSP enables cross-talk amongst engineering teams to solve complex problems and enables them to develop better and more informed product market strategies. By envisioning new and innovative systems and applications for the engineering team's existing products, it empowers the engineers to conceptualize, design and manufacture more efficient and powerful variations of their products. Advanced Engineering teams are enabled to design new products and generate new revenue streams, while simultaneously eliminating costly trial and error methods to accelerate product development and save time. The DSP connects products, systems, and applications in a physics-based modeling environment to understand the risk and reward of committing to new product developments.

CUTTING COSTS THROUGH DIGITALIZATION
ENHANCING THE POWER OF MBSE WITH THE DSP

The Future of Manufacturing and Engineering with MBSE

MBSE is the future of industry planning and manufacturing, and encapsulates a revolution in communication capabilities and processes that carry with them a variety of procedural benefits that any organization would find value in. But MBSE on its own serves only to stream-line and improve existing development processes in a new and superior digital environment. MBSE platforms, as the environments in which digital threads and digital twins are created, run the risk of establishing dated engineering methodologies in superior digital environments.

Traditional design processes reliant on experiential knowledge, historical data, numerical simulation, and probabilistic models of product capabilities, can be better implemented than they are at present, but without truly eliminating the risks and shortcomings of such methodologies. With the rapid changes we are experiencing in various engineering industries, and the exponential increase of new technological developments with limited historical data, it is increasingly dangerous to rely on prior field data, numerical simulation, and test-to-pass testing. For companies to succeed, they must undergo a comprehensive digital transformation that goes beyond simply moving their operations to digital platforms, and escape the confines of traditional, probabilistic, and experience-based product development processes.

The DSP empowers an organization to capture all the benefits of adopting the MBSE methodology, providing engineers with a collaborative platform to design and qualify complex products against different applications, and to create a single digital thread that connects all the aspects of their product development, from design, to testing, to manufacturing, and finally to field monitoring in order to give all stakeholders an integrated view of a product throughout its life cycle.
The DSP goes further than typical MBSE platforms in that it facilitates the computer aided-implementation of our patented IRM engineering methodology and uses physics-based analytical models as the basis of these digital threads and the system models that represent the product in development or production, enabling the necessary transition to deterministic development processes.

"We must boil it down to first principles, to generate physics-based life models, which will increase reliability for new components without historical data, in order to eliminate recalls."

-Payman Kianpour, M.Sc, M.Eng, P. Eng
Director, Kepstrum Inc.

Kian Kreda, B.A.
Research & Business Development, Kepstrum Inc.

Siavash Kianpour, B.Comm
Business Development Lead, Kepstrum Inc.

Kepstrum

INVENTOR OF PRODUCT DNA™ and MODEL-BASED PROGNOSTICS

Jul 17th, 2023

THE MISSING LINK IN VIRTUAL VALIDATION

Keywords: Concept-to-CAD, Digital Specification, DNA Structured Platform, Industry 4.0, Intelligent Reliability Methodology, Model-based Systems Engineering, Original Equipement Manufacturer, Prediction for product failure modes, Prediction of product´s true life expectancy, Systems modeling language, Tier Supplier, Unified modeling language, Virtual System Work, Virtual validation.

Engineering industries are undergoing a series of changes that put advancements in design technology and novel digital prototyping processes at the forefront of what they'll be able to achieve in the future. Digital management of processes, digital modeling of components, and digital tracking of design and field data are slowly becoming the norm. In this rapidly shifting and highly competitive environment, designing and developing components for emerging applications and cutting-edge technologies through continued reliance on historical data, physical testing, and multiple prototyping cycles filled with re-work is no longer a viable strategy. Companies have an incentive to pursue digitalization on the basis of achieving two distinct but related goals; increased efficiency and reduced risk.

If adopting new processes and tools to improve efficiency and reduce risk was once an amorphous goal that organizations pursued with incremental changes simply to improve their offerings and processes, it has now become imperative for them to do so in order to maintain their position in the value chain. Industry 4.0 is here, and **Original Equipment Manufacturers** (**OEM**s) are already openly moving to adopt 100% **Virtual Validation** (**VV**) methods, with some hoping to do so in the next five years. Moreover, they plan to rely on their suppliers to implement the necessary changes in their internal development processes to achieve this goal.

Tier suppliers are expected to:

- Establish their own internal **Design Verification** (**DV**) plans and new development processes that enable moving away from relying on various levels of physical testing and hardware.
- Establish systems and processes that facilitate the use of virtual tools and technologies that allow OEMs and their suppliers to leverage mathematical tools, access material data, utilize virtual models, and conduct simulations to enhance & streamline system work.

Among the goals encompassing the move to 100% Virtual Validation are:

- reducing development time
- improved engineering quality
- greater throughput
- reduced costs

Suddenly the two goals of reducing risk and increasing efficiency have taken a less ambiguous shape, with clearer outcomes now being defined; The ultimate result of such a complete transformation would be that the first physical prototypes to be produced would already be "good enough to sell".

This seismic shift in the market poses new challenges for OEMs and Tier suppliers. Pursuing either the goal of increasing efficiency or reducing risk in isolation will not suffice in this endeavor and will leave engineering organizations exposed to unwarranted risk or unable to remain competitive in the market. Thus, to achieve sustainable benefits and remain competitive, organizations must take an integrated approach to implementing new development processes that can achieve both goals simultaneously, and wherein the pursuit of either goal complements the other. Organizations must choose suitable methods to virtually model component behavior, ensuring their models accurately represent physical products and real-world conditions, and adopt **Model-based Systems Engineering** (**MBSE**) practices to facilitate streamlined system work. The ability of Tier suppliers to meet this demand will determine whether they will be able to continue receiving business from OEMs. There are bound to be many approaches to meeting this demand, but the challenges remain the same, and thanks to its robust MBSE environment, physics-based modeling, and embedded deterministic risk reduction methodology, Kepstrum's **DNA Structured Platform** (**DSP**) is uniquely suited to addressing them.

Virtual Validation & Virtual System Work: Traceability is the New Reliability

In order for Virtual Validation processes to deliver products that are good enough to sell without extensive prototyping, all steps in the production life cycle must be in lockstep. Even if the modeling that informs the understanding of a component's real-world behavior is done perfectly, it will not be enough unless the modeling delivers the intended result outlined in the product requirements. Similarly, subsequent manufacturing processes must deliver the physical product as designed. Thus, reliability goes hand in hand with traceability. In that respect, the appropriate Virtual Validation tool must also be the appropriate system work platform. This necessitates the implementation of MBSE processes that enable traceable management of technical data, design decisions, production procedures, and organizational knowledge.

As discussed in our white paper: "Cutting Costs Through Digitalization - Enhancing the Power of MBSE with the DSP":

> "...these benefits should be pursued simultaneously within a Model-based Systems Engineering platform; "MBSE is a formalized methodology that uses models as the center of system design, as opposed to document-centric engineering. It supports the requirements, design, analysis, verification, and validation associated with the development of complex systems."[1] MBSE enables an organization to create and manage a single digital thread, "a data-driven architecture that links together information generated from across the product lifecycle and is envisioned to be the primary or authoritative data and communication platform for a company's products at any instance of time"[2]. A digital thread "connects traditionally siloed elements in manufacturing processes and provides an integrated view of an asset throughout the manufacturing and product lifecycle."[3]"

Virtual modeling, design, and validation will generate the most value with the least friction in an integrated MBSE environment that allows for the creation of digital threads, cross talk between stakeholders, collaboration between teams, and traceability throughout the development process. However due consideration to the suitability of the solutions that a MBSE enhanced process,

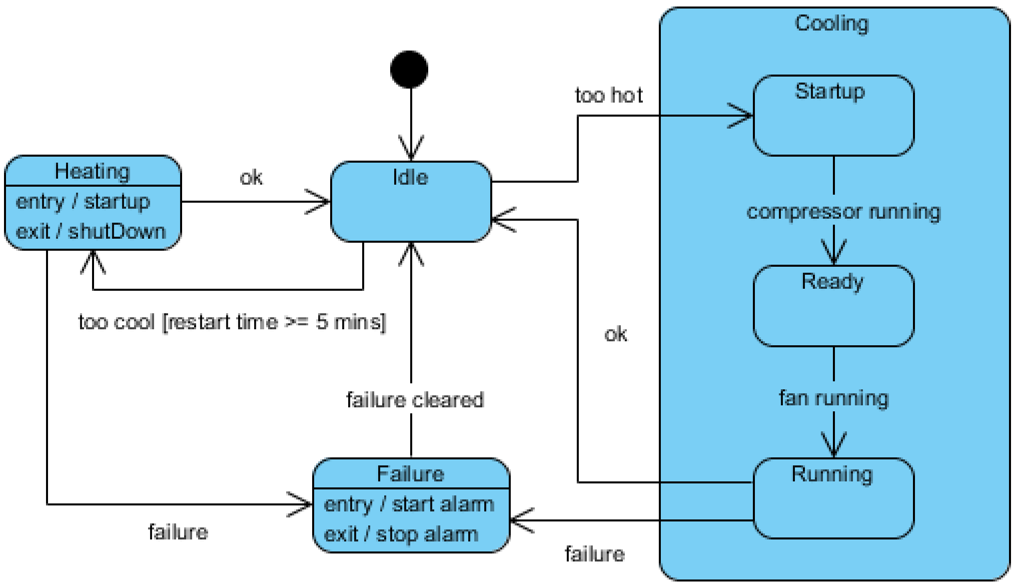
1. Shevchenko, Nataliya. "An Introduction to Model-Based Systems Engineering (MBSE)." Carnegie Mellon University, Software Engineering Institute's Insights (blog). Carnegie Mellon's Software Engineering Institute, December 21, 2020. http://insights.sei.cmu.edu/blog/introduction-model-based-systems-engineering-mbse/. Accessed 29 Jan 2023
2. Singh, Victor, and K. E. Willcox. "Engineering Design with Digital Thread." AIAA Journal, vol. Volume 56, no. Number 11, 2018, pp. 4515-4528. Aerospace Research Central, https://arc.

focused on improving project delivery, delivers must be woven into every step of the development process. For engineering reliable components, the content of the digital thread and the structure of the MBSE system used to host it play a crucial role. This will be discussed in the next section.

The Risks of Virtual Validation: Choosing the Right Path

Eliminating physical testing means confidence in the reliability of the models used to validate designs stands as one of the most pressing concerns around OEMs' plans to move to 100% Virtual Validation.

Typical MBSE platforms, based on **Unified Modelling Language** (**UML**) and **Systems Modeling Language** (**SysML**), facilitate collaboration and traceability but exhibit limitations in modeling physical behaviors and interactions. While these platforms allow for the representation of engineered components' structures using tools like UML class diagrams and SysML Block Definition Diagrams, and their behavior using tools like UML and SysML sequence diagrams, state machine diagrams, activity diagrams, and parametric diagrams, it is important to note that these modeling tools originate from the field of software and computer engineering; they are useful for defining the conceptual nature and intended behavior of a modeled system. However, when these tools are applied in the broader fields of mechanical engineering, such as the design of dynamic and structural components, their limitations become apparent. As conceptual models that define functional behavior (the intended function of a system), they are not representative models that capture physical behaviors (real word function of a system).



SysML State Machine Diagram Example for a Heater [4]

For instance, sequence diagrams represent behaviors as a single sequence of predetermined actions and outcomes. While they are suitable for capturing a linear sequence of events, they are not well-suited for modeling concurrent processes or capturing emergent behaviors that arise from the interactions between components and their environment. Similarly, state machine diagrams conceptually outline the behavior of systems transitioning between a finite number of states based on specific conditions or events. However, since they lack a built-in notion of time, they are inadequate for capturing the dynamic behavior of systems that change and degrade over

4. Visual Paradigm, "SysML: How to Use State Diagrams to Model Systems Behavior" https://www.visual-paradigm.com/guide/sysml/how-to-use-state-diagram-to-model-behavior/ Accessed 5 Jul 2023.

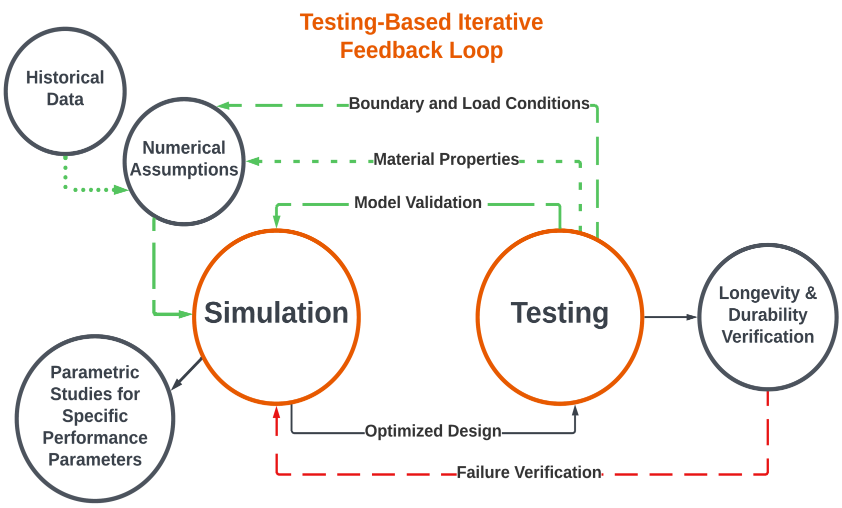
time, or how they respond to multiple simultaneous stresses.

Activity diagrams focus on the control flow of a system rather than its data flow or physical behavior. Therefore, they are not suitable for modeling the behavior of engineered components. Parametric diagrams excel at analyzing and optimizing straightforward systems with clear quantitative relationships between components and parameters. However, they do not consider the system's underlying physics or mechanics, nor do they account for the impact of external forces or stresses on its components. Consequently, they are unsuitable for modeling complex systems with multiple components and interactions, or for design projects involving research and development to discover relationships between design parameters that will be used at a later stage.

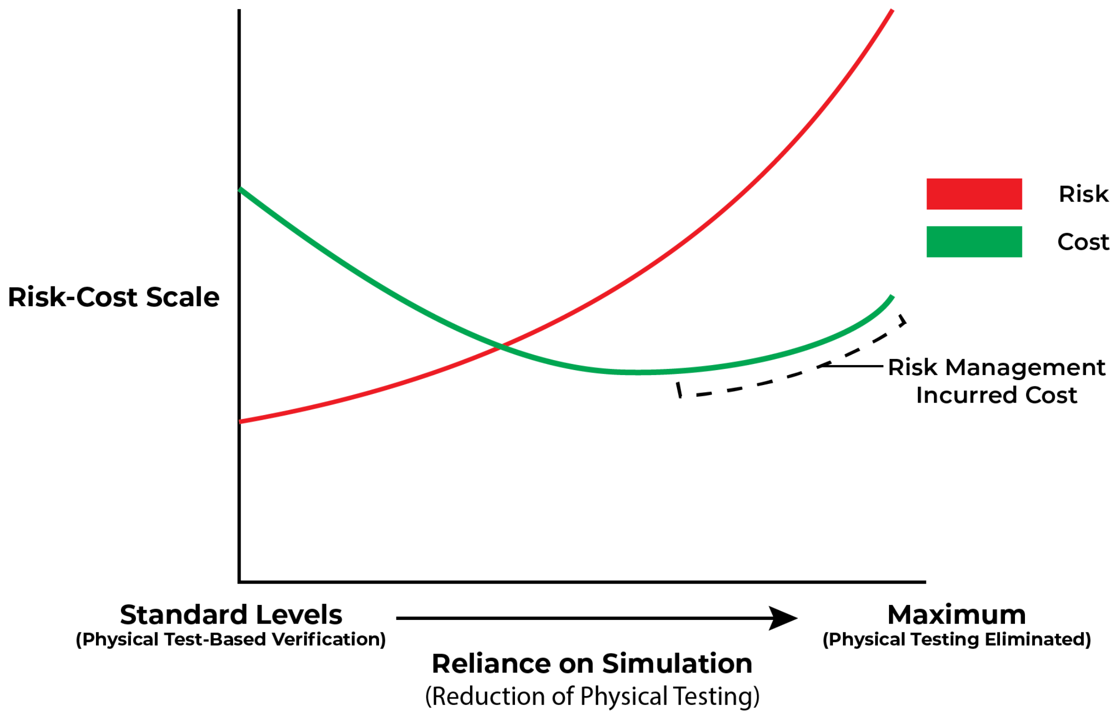
Therefore, typical MBSE tools, while beneficial for conceptually outlining intended performances, have limitations in modeling component-level behaviors and capturing the internal and external interactions of system components.

Continuous behavior, complex interactions, emergent behavior, multi-variable stress drivers, and real-time constraints must be considered when designing and validating the performance of engineered components. Without this understanding, SysML and UML MBSE languages are unable to accurately validate whether performance requirements are being met as design decisions are being made, or model the real-world behavior of a component. Thus, they cannot facilitate effective design verification or eliminate the risk of recalls. To accurately model engineered components, structure and behavior must be considered in an integrated manner in order to accurately model either. Therefore, for an MBSE-based development process to be effective in achieving 100% Virtual Validation, it must rely on other means of modeling components to evaluate design decisions and manufacturing processes.

Organizations that have implemented MBSE processes typically rely on simulation to overcome the limitations of conventional MBSE platforms regarding modeling component behavior. By combining streamlined system work, simulation, and physical testing, these organizations have achieved cost reductions and delivered successful products. However, there are inherent limitations to what this three-pronged approach can accomplish, and even with these processes, these environments are still prone to field failures and lengthy prototyping phases. Previously, simulation techniques complemented and improved existing development processes, leveraging historical data and physical test-based verification in order to build and validate simulation models.



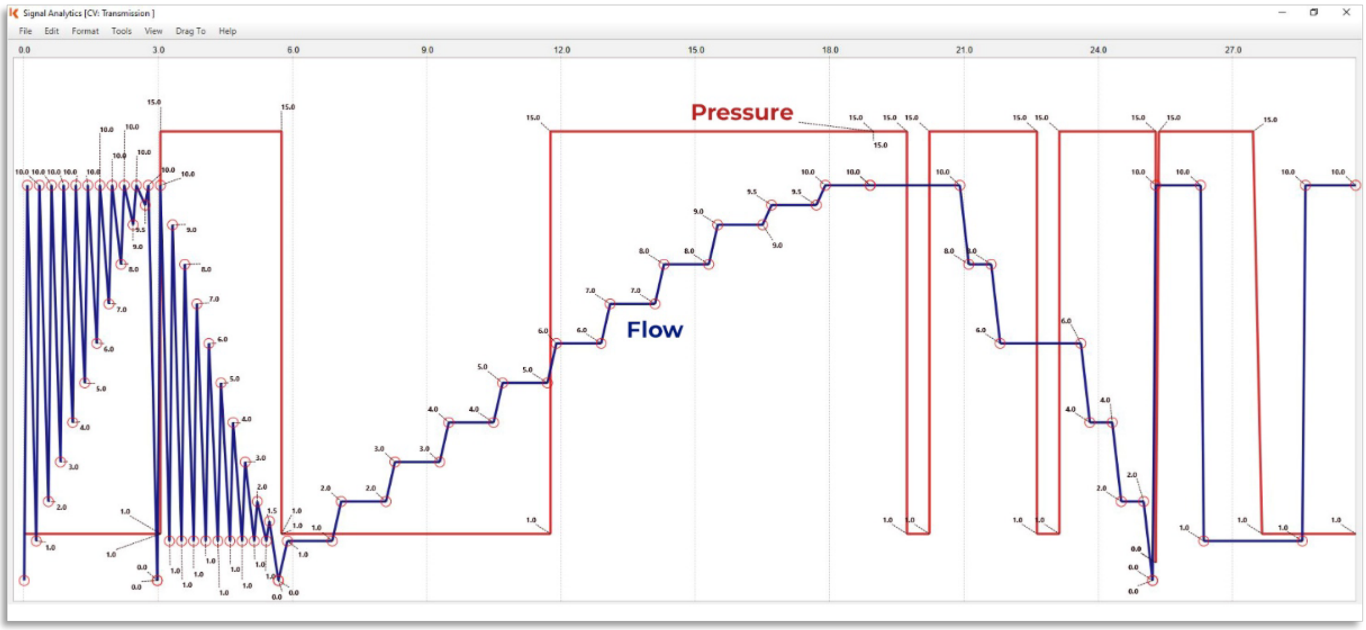
With the elimination of physical testing from the development ecosystem, MBSE processes reliant on simulation will become even more shorthanded. Simulation teams will no longer be able to iteratively inform the numerical assumptions of their models, validate their models, or rely on extensive longevity and durability testing to identify any potential failures that may have been missed in simulation. This will introduce an unacceptable amount of risk as organizations will not be able to verify that their product meets safety and performance requirements. This challenge is particularly prominent in new developments lacking sufficient historical data to inform the assumptions of numerical simulations. Furthermore the specific nature of parametric simulations means that produced results cannot be extrapolated beyond a narrow range of specific conditions. The heavy reliance on simulation in Virtual Validation can lead to misguided mistakes if an open system of definition, analysis, cycles, and stress drivers is not properly defined. The weight of this risk will only increase as organizations are pushed to supplant their physical testing processes with more simulation. This increased risk will also result in new costs associated with risk management and reputational damage, rendering the cost savings derived from the elimination of physical testing insignificant or even outweighing the initial benefits.



A successful 100% Virtual Validation process cannot be developed by simply increasing the investment in, and strain on, simulation teams, and instead requires the inclusion of an additional ingredient: physics-based analytical modeling.

DSP: MBSE & Virtual Validation the Right Way

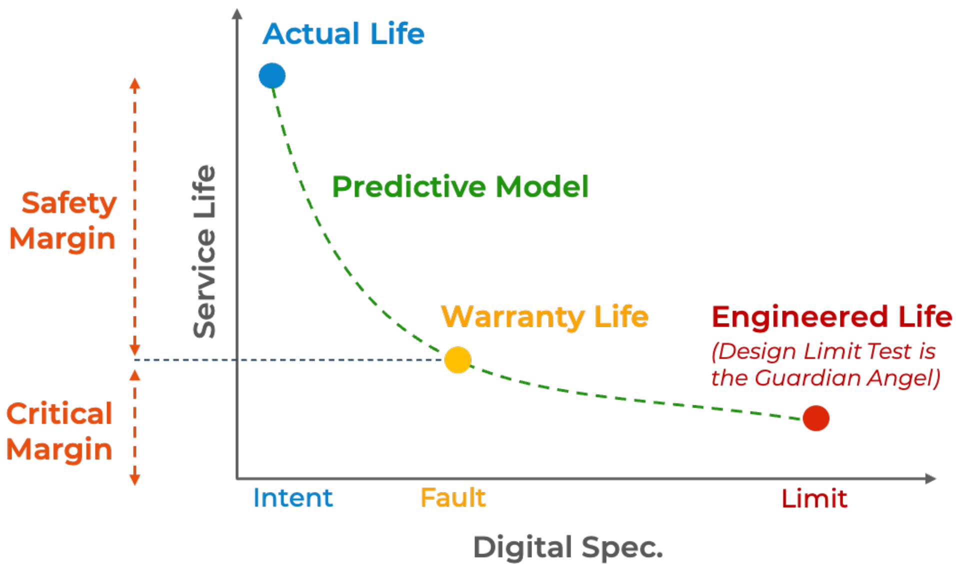
What differentiates DSP from other MBSE offerings is the embedded methods of capturing functional requirements and modeling component behavior. UML and SysML-based MBSE systems' standardized methods of capturing product requirements are heavily text-based and ultimately require diligent and manual verification throughout the design process. DSP provides the capability of capturing product requirements and then graphing them as signals on a single plot to create the component's "**Digital Spec.**" functional profile. For modeling components, we rely on analytical models as the best tool for truly understanding the capabilities, behaviors, and limitations of engineered components. To employ these models, DSP uses Digital Spec. profiles, which include the signals defining functional requirements, as a foundation and expands them to include calculated signals whose values can be related to one another and are calculated using physics-based closed-form equations. Digital Spec enables a clear visual understanding of the product requirements in the same format as the calculated signals that model the component's complex interactions, performance, and exposure to stress. This simultaneously eliminates the ambiguity and complexity of capturing complex product requirements in a text-based format and enables real-time design verification, ensuring those requirements are being met as development progresses. Furthermore, DSP allows the same models and equations to be used on these profiles to calculate the component's trend-to-failure to determine the design limit and avoid unforeseen field failures, in addition to verifying whether the product requirements have been met.



Simplified Digital Spec. Profile Example

At its core, DSP is an enterprise level database-structured software that facilitates the computer aided implementation of our patented "Method for deterministic stress based risk reduction" (Patent No. US20140081583A1), known as **Intelligent Reliability Methodology** (**IRM**), to generate a product's "**DNA**" (**D**esign Limit, **N**ature of Failure, **A**ctual Life). **Product DNA** is the culmination of the use of analytical-models and closed form equations in conjunction with deterministic analyses based on IRM. This analytical stress-life model is used to predict product failure modes (why it fails, how it fails, when it fails), and understand product capability far more accurately than conventional methods. It represents the organization's highest level of understanding about their product, and it is the tool by which organizations can understand their component's limits, safety margins, and maintenance requirements, and deliver confident predictions of a product's true life expectancy to their customers. (Diagram on the following page)

THE MISSING LINK IN VIRTUAL VALIDATION

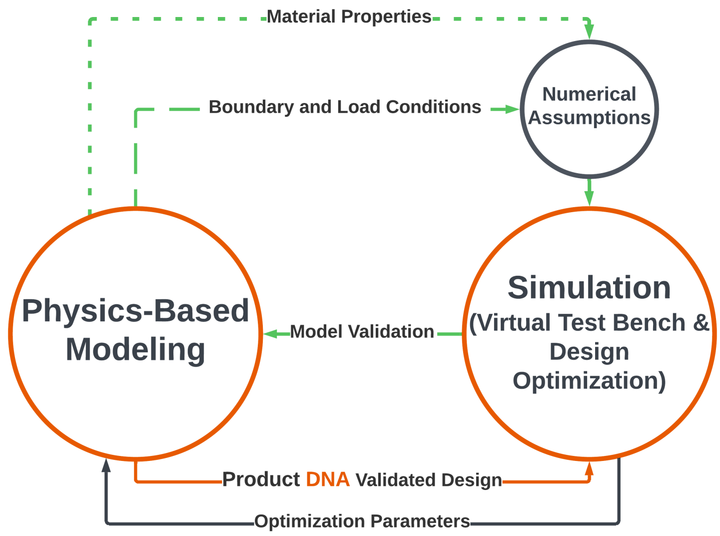


By correlating stress-drivers with how and when a product will fail, Product DNA empowers engineering teams to reveal product weaknesses and generate design solutions in the early stages of development, validate designs, and detect material variation in manufacturing. Thus, random failures become a thing of the past, and the design process becomes more effective and efficient, allowing for the actualization of the goal of producing reliable components good enough to sell at the first production batch.

DSP's physics based modeling and DNA technology has the power to enhance and complement numerical simulation models to establish a healthy Virtual Validation process. By using DSP's physics-based modeling, engineering teams are able to provide simulation teams with deterministic boundary conditions grounded in real-world physics. These boundary conditions provide essential parameters for numerical simulations, thereby ensuring the assumptions used generate reliable results. In this process, the focus shifts from CAE to Concept-to-CAD, ensuring that new products are qualified in the conceptual stage for sizing and service life before reaching the CAD stage.

Our platform's concept-phase physics-based analytics offer unlimited capacity for involving any kind of deterministic boundaries. With these deterministic boundaries in place, simulation teams can greatly enhance the reliability and applicability of their simulations and are empowered to

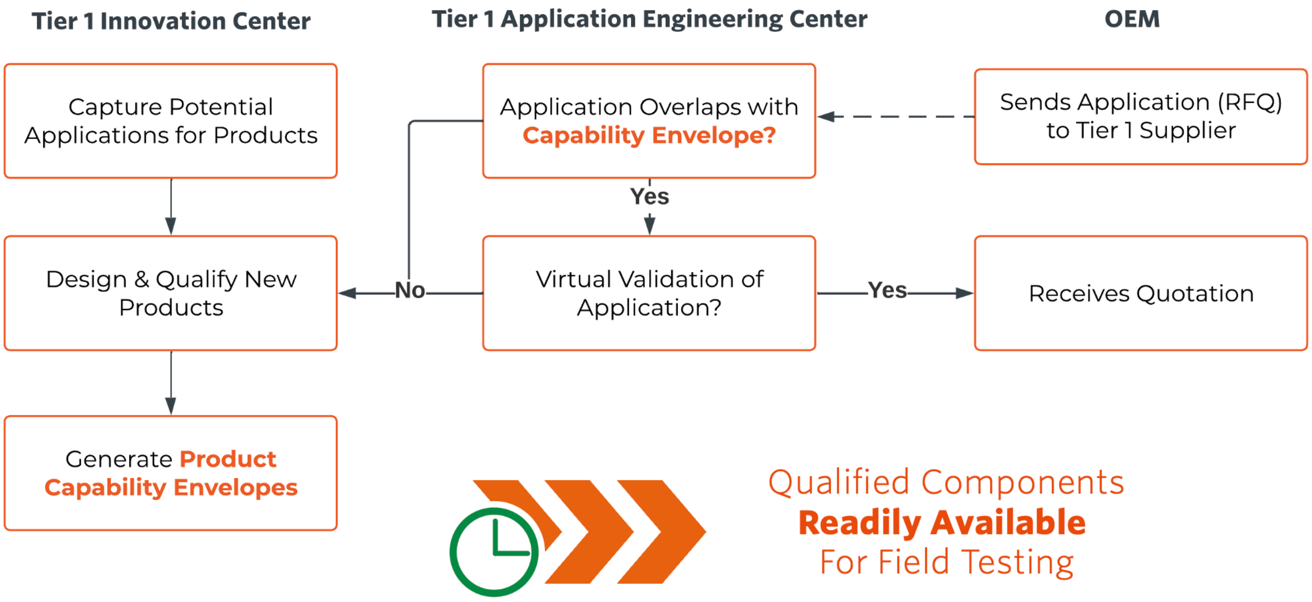
Physics-Based Simulation Enhancement



optimize designs that, thanks to DSP's DNA enhanced design process, are already capable of delivering the intended performance. By defining physics-based boundary conditions, the DSP system elevates the trustworthiness and effectiveness of simulation results to new levels, an important benefit in pursuing 100% Virtual Validation.

Qualifying Product Capability Envelopes: Respond to RFQs With Speed & Depth

Through the same modeling tools that generate product DNA, DSP is used to generate Product Capability Envelopes, profiles that provide a comprehensive definition of a product's capabilities. This unique feature allows tier suppliers to qualify the Product Capability Envelope for new products without historical data and match existing products to new applications, enabling them to be ready for OEM applications and respond to **request for quotation** (**RFQ**)s with speed and depth. A DSP enhanced process grants tier suppliers the ability to confidently understand and convey their components' capabilities, allowing OEMs to purchase them with the confidence that they will do the job "straight off the shelf", and if not, collaborate to draw a clear path to developing a component that will. With Product Capability Envelopes, suppliers' application engineering centers can quickly determine if an existing component is qualified for an OEM's provided application.



DSP: The Ideal Platform for Virtual Validation and Virtual System Development

Kepstrum's DNA Structured Platform (DSP) simultaneously addresses the risks of transitioning to 100% Virtual Validation and provides a MBSE environment that enables comprehensive and integrated virtual system work. It provides engineers with a collaborative platform wherein they create a single digital thread to connect all the aspects of product development in order to give the entirety of the organization an integrated view of their products throughout their life-cycle.

DSP enables faster and more reliable design validation, faster responses to market demand & shifting regulations, faster validation of individual components for modular inclusion in larger complex systems, and faster iterative product development to meet new requirements for new applications. DSP's integrated environment both guides progress and serves as a repository for tracking an organization's decisions, systems knowledge, and engineering know-how. This comprehensive approach gives our clients a competitive edge in today's rapidly changing markets, enabling them to reduce time-to-market, costs, and achieve stable production. By leveraging DSP, tier suppliers can embrace the OEMs' vision of transitioning to 100% virtual development and validation processes. Our platform's comprehensive capabilities, focus on accurate modeling, concept-to-CAD approach, knowledge management features, and alignment with OEM requirements make it the most suitable platform for this transformative initiative.

Author's Note:

This whitepaper was written in response to the emerging 100% Virtual Validation trend in various engineering industries, however not all OEMs are shifting to this paradigm rapidly (some are implementing it gradually). While DSP is uniquely positioned to address the needs of 100% Virtual Validation processes, it is also intended for full PLM integration in development processes that still use physical testing. DSP allows for the direct export of Digital Spec. profiles as test protocols to test machines and the direct import of test results back to DSP for analysis and comparison against the intended performance and modeled behavior of engineered components. In such use-cases, DSP is a valuable tool for enhancing physical testing processes. In addition, the use of Product DNA in the development process can allow for the replacement of lengthy durability and longevity tests with model-based design limit tests, and the reduction of prototyping iterations by revealing product weaknesses in early design stages. DSP is a robust tool that can complement or transform your development processes depending on the degree to which your organization leverages its capabilities. Please visit kepstrum.com to learn more about how you can use DSP to enhance your development process at any stage.

Kian Kreda, B.A.
Research & Business Development, Kepstrum Inc.

Siavash Kianpour, B.Comm
Business Development Lead, Kepstrum Inc.

Kepstrum
INVENTOR OF PRODUCT DNA™
and MODEL-BASED PROGNOSTICS

TRACEABLE KNOWLEDGE

DSP's Foundation for Advanced Engineering

Abstract

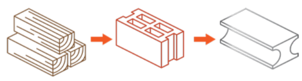
As engineering industries evolve with technological advancements, changing customer demands, and regulatory shifts, there is an unprecedented demand on engineering organizations to upgrade their existing technologies and develop new ones at break-neck speeds, all while **Original Equipment Manufacturers (OEMs)** are pushing to move to Virtual Validation methods in the near future. To successfully meet these challenges, organizations must employ new methods of converting their members' knowledge and experiences into lasting knowledge assets that are accessible, transferable, and reusable. This shift necessitates overcoming the limitations of traditional file-based knowledge management, risks like organizational silos, opportunity costs of immobilized experience, outdated practices, and challenges in integrating new engineers. Kepstrum's **DNA Structured Platform (DSP)** offers a solution for advanced engineering teams by serving as an integrated knowledge management and virtual system work platform that digitizes knowledge, traces decision rationales, and formalizes a model-based development process built on the use of analytical modeling. This integrated approach provides a stable foundation for Virtual Validation practices by ensuring important information is accessible to the entire organization, empowering engineering teams to reduce testing, shorten development times, and rapidly respond to **requests for quotation (RFQs)**.

Things Change...

- **Production lines move**
- **New Complex Problems Emerge**

- **People Retire**
- **Policies change**

- **Products change**
- **Materials Change**



When things change, knowledge gaps and disconnects occur...

DSP's traceable knowledge has the solution!

In the modern economy, the transition from resource-based models to knowledge-driven ones is apparent, particularly in sectors like manufacturing and engineering, where knowledge is now the primary driver of innovation and economic growth. While the experience and knowledge of an organization's engineering teams are invaluable assets for developing new technologies and improving existing ones, organizations face challenges in fully harnessing them. At the same time, in a rapidly changing business landscape, solely relying on individual experience can also lead to organizational silos, missed opportunities, challenges in integrating new hires, and inefficiencies that hinder an organization's ability to adapt and achieve consistent growth.

Challenges: The Risks of Relying on Experience

Experience, while important, can become a crutch that inhibits progress and innovation. Reliance on individual experiences can pose substantial risks for engineering companies and impede the broader dissemination of knowledge, resulting in organizational silos and a lack of synergy. There is the risk that experience relevant to multiple organization-wide endeavors can be

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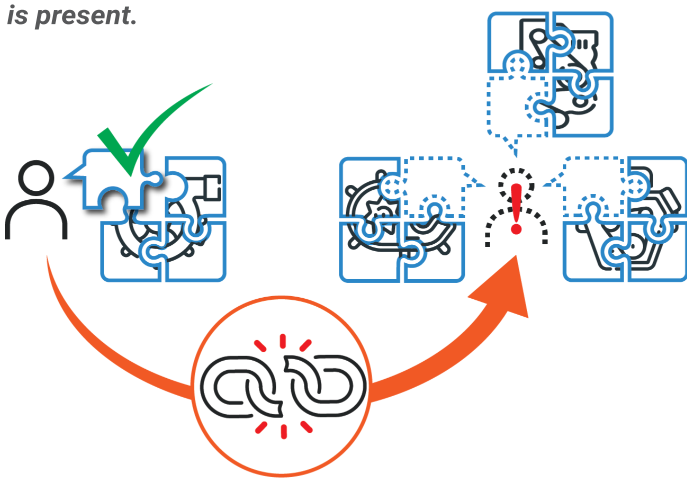
missed, and valuable insights and expertise that could contribute to diverse projects and initiatives may be overlooked. A narrow focus on individual experiences may inadvertently lead to the exclusion of alternative perspectives and innovative approaches, limiting the organization's ability to explore new avenues and optimize outcomes.

The Opportunity Cost of Immobilized Experience

In Lean Thinking, making use of your employees' talents isn't just a good thing, not making use of them is a bad thing. This problem scales up when you take into account that having an experienced person who is idle is only part of the larger problem of their experience itself being idle at the organization. If the experience of individuals is not harnessed and converted into tangible usable processes, transferable knowledge, or organization-wide understandings, its benefits will only be available to the organization and the individual's immediate peers ***while the individual is present.***

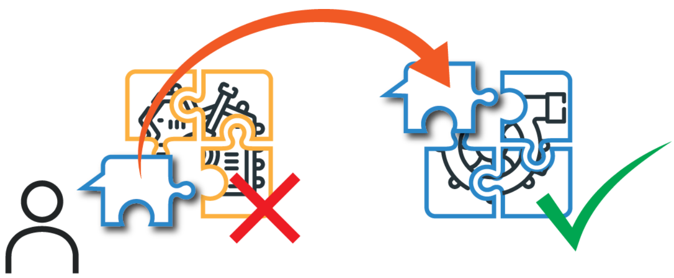


An engineer cannot be in two places at once; their experience may be the missing link for other projects

Outside of the mmediate results that the individual and their team generate, the organization as a whole fails to maximize their benefit from the leveraged experience. When an engineer's experience is contributed to one project, it is essentially unavailable to the rest of the organization until the engineer is available again. project, it is essentially unavailable to the rest of the organization until that engineer is available again. To address these challenges, organizations must adopt a Lean Thinking approach that not only makes use of employees' talents but also avoids the opportunity cost that occurs when their experience is localized.

The Risk of Relying on Outdated Experience

As technology evolves and market demands shift, the opportunity cost of idle experience is compounded by the risks of relying on experience that is outdated or unsuited to specific tasks. Outdated experiences may not align with emerging trends and evolving technological standards, leading to suboptimal solutions and potential setbacks, while experience that is unsuited to the unique requirements of a particular project can result in ineffective problem-solving and inefficient resource allocation. To mitigate these risks, engineering companies must recognize the need to balance experience with continuous learning and the integration of new knowledge. Experience must not only be converted into an easily accessible asset, but an easily interchangeable and amendable one, wherein the experience and knowledge used is always retrieved from an up-to-date collection of all available knowledge, guided by the assessment of its suitability to the task at hand. Organizations must simultaneously strive to eliminate the risk of relying on outdated experience as well as missing out on the use of relevant experience.



Experience that is unsuited to one project may still be helpful to other teams

Integrating the Next Generation of Engineers

Another challenge that organizations face from experience-reliant development processes is the rapid integration of the next-generation of engineers into their ranks. As management hires junior engineers, they are expected to contribute to development processes

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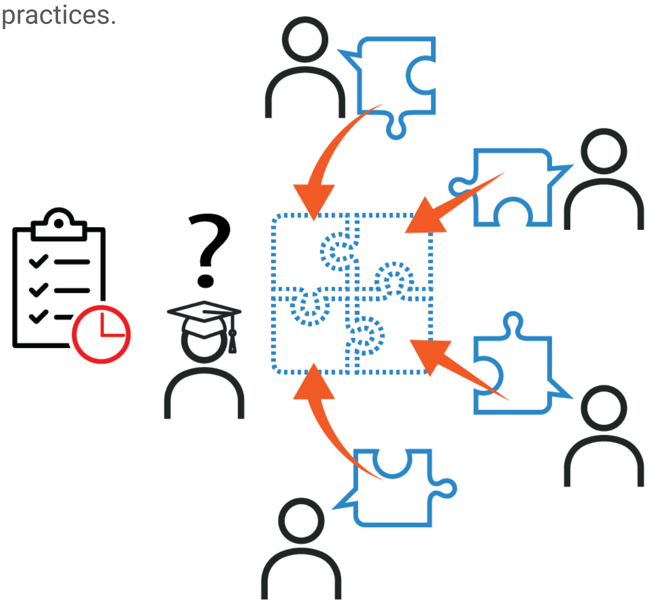
that are heavily reliant on experience they may not possess, and which can take significant time and effort to acquire. Consequently, training is a dual front task. Firstly, new engineers must familiarize themselves with formalized practices and processes. Secondly, they must bridge the knowledge gaps that exist between them and their experienced peers, particularly in terms of non-standardized problem-solving methods and best practices.

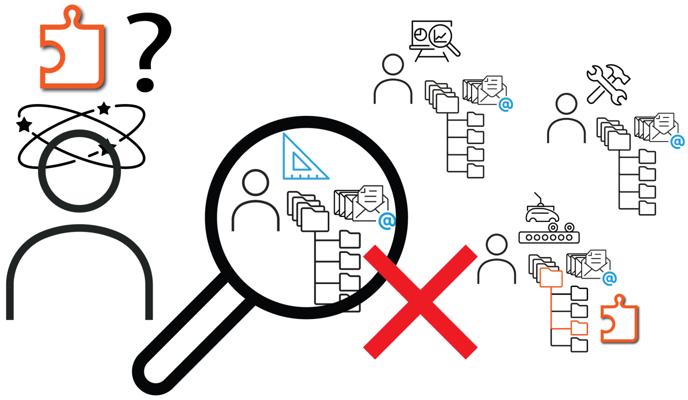


Entry-level engineers need time, and access to multiple colleagues, to fill their knowledge gaps

This two-fold process of ensuring new engineers are effectively trained not only requires significant time and resources, but also exposes them to the aforementioned risks of inadvertently learning outdated or inefficient practices in an environment where the knowledge base is not being proactively managed. Moreover there is a risk that the fresh perspectives and up-to-date physics knowledge of new graduates could be overlooked in favor of continued adherence to established processes and deference to more senior engineers who do not have the means to easily adjust their own practices. To overcome these challenges, there must be a way for entry level engineers to easily access and understand the information in the organization's database, as well as a structural shift that inspires all employees to adopt change by actively using and contributing to an interactive knowledge base.

The Limits of File-Based Knowledge Management

The value of an individual's experience cannot be understated, but experience is a personal phenomenon, with its value to the individual and to the organization depending on their mutual ability to apply and learn from it. In building a healthy knowledge base, organizations face the challenge of effectively harnessing an organization's wealth of experience while mitigating the risks associated with overreliance on that experience. However, it is not sufficient to merely accumulate knowledge, in haphazard forms, in sprawling and disconnected repositories, as this can lead to confusion and disorganization.



It can be difficult to find the right answers amongst files, e-mails, and disconnected knowledge repositories

A file-based and unstructured approach to knowledge management can result in a number of problems. Files are as personalized as experience, with naming conventions and locations of files being left to individuals. Inconsistent terminology and inadequate document tagging on the part of individuals can impede information retrieval, and the lack of a structured system can make it challenging to efficiently search for specific information. Furthermore, as changes are made and files are passed from one person or team to the next, it becomes increasingly difficult to keep track of the most up-to-date information between the multiple versions that are scattered across the organization.

Ironically, in this context, experience is required to navigate the knowledge base, and sometimes the only way to find important information is to already know where it is located. If the individuals who know what a file was named, where it was placed in the repository, and whether or not it is the most current version happen to leave, that knowledge will be hard to access thereafter. This is in addition to the knowledge gap that is created by the departure of that individual whose experience, in terms of knowledge and practices, may not have been well documented or converted into formalized practices.

In the same way an individual's experience is localized, critical information in files may become isolated within specific departments or teams. Without a well structured central repository, duplicated efforts may occur unknowingly, and managing access to sensitive documents becomes problematic. Additionally, documents often lack context or decision-making rationale, making it challenging for all employees regardless of seniority, to understand past decisions. Changes in regulations or industry standards pose a risk as well, as outdated documents may lead to non-compliance and legal issues. All of these limitations underscore the importance of adopting a structured and comprehensive knowledge management system.

Building a Healthy Knowledge Base

Addressing these challenges requires a shift in both development processes and knowledge management methods, where they become integrated with one another. Furthermore, in the context of solving engineering problems and making engineering know-how transferable and accessible, the development process must be structured around the use of physics-based models.

In order for an engineer's experience to be transferable, it must be transformed into knowledge that can be understood and accessed by all engineers in the organization. There are two fundamental dimensions to any engineer's experiential knowledge:

1. The engineering know-how that encapsulates their understanding of a product's function, mechanisms and material properties.
2. The process know-how that encapsulates their understanding of how their team makes decisions and executes tasks related to designing, modeling, testing, and manufacturing a product.

To capture an individual's engineering know-how, the content of the development process they partake in must be based on the use of physics-based models, while their experience and knowledge that falls outside of the realm of physics based-understandings should be captured and integrated into a digital framework that aligns with the development process itself. An effective knowledge base must be integrated into the development process, not stand outside of it. This necessitates the use of a **Model-Based Systems Engineering (MBSE)** platform that manages a physics-based development process in a virtual environment while serving as a centralized knowledge repository that links the various kinds of knowledge and data used to the steps of the process in which they are used.

Kepstrum's DNA Structured Platform (DSP) is an enterprise-level MBSE platform that embodies this integrative and physics-oriented approach. DSP serves as a centralized knowledge management and virtual system work platform that ensures important information is accessible to the entire organization and not localized to individual engineers.

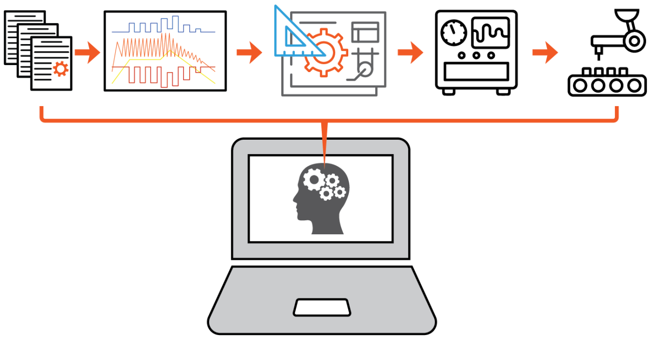
What is MBSE?

Model Based Systems Engineering is "a formalized methodology that uses models as the center of system design, as opposed to document-centric engineering. It supports the requirements, design, analysis, verification, and validation associated with the development of complex systems."[1] A mature MBSE environment provides a platform for collaborative virtual system work, enabling an organization to create and manage a single **digital thread**, "a data-driven architecture that links together information generated from across the product lifecycle and is envisioned to be the primary or authoritative data and communication platform for a company's products at any instance of time"[2].

A digital thread helps to overcome many of the previously mentioned issues with file-based knowledge management and "connects traditionally siloed elements in manufacturing processes and provides an integrated view of an asset throughout the manufacturing and product lifecycle."[3] A robust digital thread is the basis for

1. Shevchenko, Nataliya. "An Introduction to Model-Based Systems Engineering (MBSE)." Web log. Carnegie Mellon University, Software Engineering Institute's Insights Dec. 2020
2. Singh, Victor, and K. E. Willcox. "Engineering Design with Digital Thread." AIAA Journal, vol. Volume 56, no. Number 11, 2018, pp. 4515-4528.
3. Diann, Daniel "Definition: Digital Thread" https://www.techtarget.com/searcherp/definition/digital-thread.

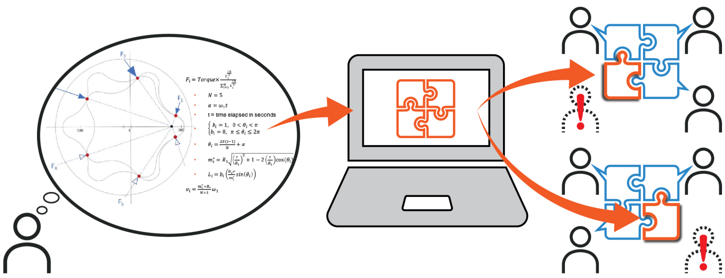
making information more accessible, and processes and decisions in a product's life cycle more traceable. What distinguishes DSP from typical MBSE platforms is the integration of physics-based models as the basis of the virtual system work that the system facilitates.



A digital thread connects all aspects of product development in one virtual platform

Capturing Engineering Know-how

To successfully capture an individual's engineering know-how, product designs must be broken down in terms of the underlying application of physics and understanding of material properties that together define the product's function and limitations. DSP empowers engineers to use scientific and engineering principles to solve problems and develop new processes, products, and technologies. DSP empowers engineering teams to consolidate their expertise into new physics-based models, while also providing a platform to document, manage, and integrate these models into their development process. When this central use of physics-based models is formalized and built into the virtual systems they use, engineers will inherently express their decisions and designs in terms of the first principles they are using. With this analytical approach, not only will an organization be able to convert their engineer's knowledge into physics-based models that can be flexibly utilized across the organization, it will also be able to successfully employ virtual validation methods that necessitate the use of physics-based modeling in order to enhance simulation and reduce costly testing.



DSP digitizes an engineer's know-how, making it accessible organization-wide, even when the individual isn't available

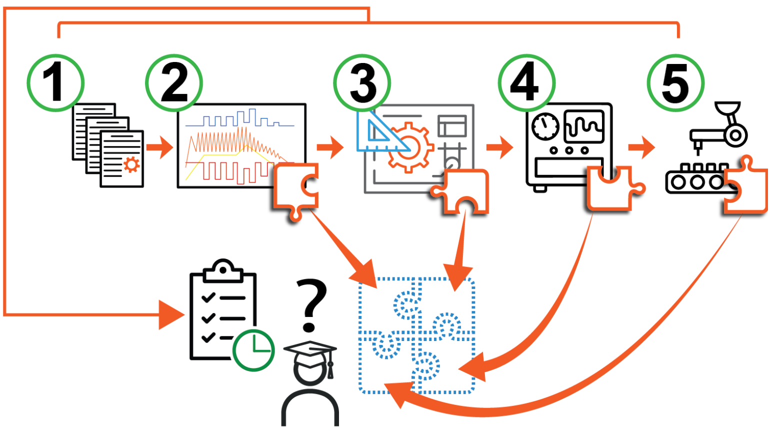
DSP's Knowledge Management Structure

Lastly, to make organizational knowledge, including both dimensions of engineers' experiential knowledge, accessible organization-wide, the knowledge repository must be integrated into a structured development process. This ensures that relevant knowledge is accessible at the point at which it is used, or captured at the point at which it is generated. An organization's development process corresponds to the day-to-day operations of its members, mapping out where and when specific types of knowledge are used and generated. Therefore, if the knowledge management system is structured around the development process rather than being a separate file-based repository, all engineering know-how, process know-how, and other forms of technical data can be systematically documented in relation to the aspect of the development process to which they are related.

When decisions are made in a virtual environment built around a single digital thread that links data directly to the interface where those decisions, designs, and protocols are managed, knowledge is automatically captured and readily accessible to anyone involved in the process. This elevates experience to a lasting and shareable asset while eliminating communication and comprehension gaps that typically arise when changes occur in an environment with a disjointed knowledge management process.

DSP's knowledge management tools allow organizations to transition from using traditional file-based knowledge repositories to employing knowledge "maps". Within the platform, existing knowledge and files can be effortlessly uploaded and linked to the specific steps in the development process where they are used. DSP has a built-in version control system, enabling constant updates to the files linked to the development process. Previous versions are easily accessible, and the rationales for changes are logged. Furthermore, all data, pages, and files in DSP can be interlinked to reveal relationships that might otherwise be overlooked. Previously, these relationships might only have been understood by those with the relevant experience and those who they explained them to in a specific in-person or e-messaging communication chain. To document such relationships would require generating another file that could be easily lost or forgotten over time, and valuable scientific insights that might be useful to other projects would remain localized.

Using DSP's knowledge management tools, all information can be correlated and presented within an intuitive network, offering an unprecedented level of traceability for decision-making rationales, while scientific knowledge and physics-based understandings can constantly be documented in a globally accessible physics library, eliminating knowledge silos between departments and teams and allowing for new and existing physics-based understandings to be seamlessly employed by any teams that stand to benefit from it. With this framework, new team members can seamlessly integrate into the organization, leveraging a foundation rooted in applied physics, and all of the organization's members can access knowledge precisely where it's needed at different stages of the development process.



Entry-level engineers can use DSP's digital thread to intuitively access all the process and engineering know-how they need to fill their knowledge gaps

Conclusion

In engineering, individual experience is important for problem-solving and project success. However, organizations struggle with effectively leveraging this experience without being overly reliant on it. Organizations must adopt processes that transform an individual's knowledge and experience into lasting assets that can be used across the entire organization, even when that individual is not available. Moving beyond file-based knowledge repositories, a robust MBSE platform with integrated knowledge management is needed—one that captures valuable experience while ensuring it is easily accessible, transferable, and scalable.

Capturing engineering know-how in the universal language of physics is fundamental for transferability, while linking this knowledge directly to a digitized development process ensures its accessibility. Kepstrum's DSP addresses both of these requirements by formalizing a model-based development process built on a foundation of using physics-based models (that embody the organizations' collective engineering know-how) and also serves as a centralized knowledge management platform that links data to the steps of the process that use it, and traces decisions made in the development process to the underlying knowledge that informed them. This ensures that engineering physics & principles are retained, transparent, traceable, and globally accessible, making them transferable across generations of engineers and products.

This approach helps to facilitate greater collaboration, continuous learning for all teams, increased organizational knowledge retention and traceability, and the faster training and mobilization of new graduates, who have fresh and up-to-date understandings of physics-based models. A healthy digital ecosystem with a robust knowledge base and a physics-based approach to virtual system work is a necessary foundation for successfully employing virtual validation methods to reduce testing, shorten development times, and rapidly respond to requests for quotation (RFQs).

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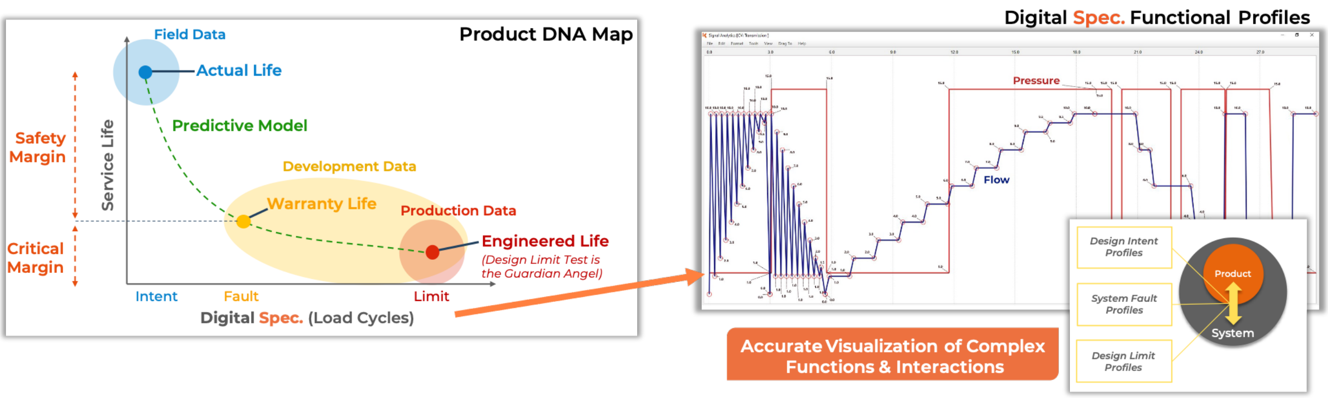
About Kepstrum:

Kepstrum is the inventor of **Product DNA** (**Design Limit, Nature of Failure, Actual Life**). With core competencies in engineering physics and software engineering, it is the patent holder of deterministic risk reduction methodologies and technologies to map Product DNA, through its innovative software platform, named Kepstrum's DSP.

Kepstrum's DSP (**DNA Structured Platform**), is an enterprise-level collaborative software with a revolutionary digitalization approach. DSP replaces files with maps, and words with profiles to generate digital specifications (**Digital Spec.**) that are used as inputs to its engineering analytics to configure product mechanisms and predict failure-life models (**Product DNA**).



DSP empowers Advanced Engineering Teams to use scientific and engineering principles to solve problems and develop new processes, products, and technologies. DSP ensures that Model-Based solutions are retained, transparent, traceable, globally accessible and transferable to the **new generations of engineers and products**. DSP revolutionizes the traditional transformation of "Applications to Product Functions" using the "Digital Spec. to Digital DNA" process. DSP enables R&D engineers to predict the concept's DNA, in less than 8 weeks, as the fundamental step to meet OEM's new **Virtual Validation** demands. DSP provides organizations with a significant analytical bandwidth to compete in this agile market shift using limited resources.

Kepstrum's mission is to advance **Model Based Systems Engineering** (**MBSE**) by commercializing **physics-based analytics** and is an advocate for the adoption of **deterministic design** processes (by removing random features at the conceptual level) for new developments without history over traditional experience-based and probabilistic design methods.

Authors:

Kian Kreda, B.A.
Research & Business Development, Kepstrum Inc.

Siavash Kianpour, B.Comm
Business Development Lead, Kepstrum Inc.

SHIFT IN MINDSET

June 25, 2020

Over the years, we have been trying to understand Canada's position in the global economy. There is an underlying question that we need to ask ourselves as Canadians: how do we instill a proactive mindset?

The Article, *Homegrown ideas need our support*[1], discusses the need for adopting new technologies created in Canada.

We have great incentives in this country which lower taxes and provide financial support such as SR&ED and NRC-IRAP. However, to lead the global economy in any sector, we must first support our new technologies right here in our own backyard.

Countries that have been dependent on **developing new industries as a main source of their GDP** are more receptive to new technologies. This in turn results in the creation of a proactive mindset. This includes nations that are not solely dependant on natural resource economies, which also design and manufacture their own technologies. Yes, 10% of Canada's GDP is in manufacturing[2], but do we own all the designs, or are we mainly operating based on "build to print"?

In *Homegrown ideas need our support*, Germany, South Korea and the United States are listed as nations that are supportive of homegrown technologies. Let us overlay our consensus, after years of experience in the automotive industry.

Germany, having a strong automotive market, and is home to leading OEMs and manufacturers, has been designing and manufacturing automobiles for over a hundred years. They are not dependant on natural resources for GDP. For that matter, our company, Kepstrum Inc., has had great success promoting our technology in Germany, as they are receptive to new technologies.

South Korea - home to auto OEMs including Hyundai and Kia Motors, is also a major player in the consumer electronics markets. Their leading brand, Samsung, is competing in Apple's playing field. Let us not forget Samsung's automotive segment, which is now Renault Samsung Motors.

USA, despite its large oil reservoirs, is not solely dependant on natural resources for GDP. The country is a leading automotive market and is home to influential technology companies that have reshaped our day to day lives, such as Apple and Microsoft.

Japan, although not mentioned, is home to several leading auto OEMs, such as Toyota, Honda, and Nissan. As they are known to build reliable and long- lasting vehicles, it has allowed their brands to develop the world's top selling models, such as the Toyota Corolla[3]. The nation is not rich in natural resources, and as a result, they are now leaders in automotive and consumer electronics.

The same way that Hydrostor, the world's leading developer of Advanced Compressed Energy Storage, piloted in Canada but looked to Australia to scale[1], Kepstrum experienced the same in the past, finding initial projects in our own backyard, but looked to Germany and Austria to scale.

The question still lies, how do we instill a shift in mindset?

Let us examine a controversial topic of our global economy; the leap towards reducing carbon emissions. Various industries are adopting this change regardless of the impact on the bottom line, as we progressively battle climate change.

In automotive, the industry is looking to reduce emissions heavily by introducing new electric powertrain components. Although Canada is home to several major parts manufacturers, our nation needs a stronger investment in Canadian OEMs, in other words, domestic usage. In return, reducing the need for auto designs and strategic directions to be controlled from outside the nation. This allows our country to be less vulnerable to shifts in global consumer demands, or else we will experience the same episodes as the closures of GM in Oshawa and FCA in Windsor, which leaves thousands without jobs. We must encourage our parts manufacturers to focus on controlling designs and leading new development technologies. But without the counterparty usage

1. Wu, Y. "Homegrown ideas need our support". 2020. Toronto Star
2. Statistics Canada. Table 36-10-0434-03 Gross domestic product (GDP) at basic prices, by industry, annual average (x 1,000,000)
3. Focus2Move. "Global Auto Market. The ranking by manufacturer in 2019". 2020. Focus2Move

from Canadian OEMs, we are not supporting our ecosystem for homegrown technologies. It is time we close this loop and invest in domestic collaboration and usage.

As mentioned previously, our government is providing the programs and financial support in place to facilitate this collaboration amongst Canadian peers. But it is up to us to take that initiative. SR&ED and NRC-IRAP are providing research funding. Next Generation Manufacturing Canada (NGen) is providing the marketplace to facilitate collaboration between manufacturing companies and technology providers. This helps support our ecosystem for the adoption of new technologies. With their commitment to invest $192 million into the sector within a few years, it encourages matchmaking to drive new technologies forward, and hopefully provide birth to automotive OEMs.

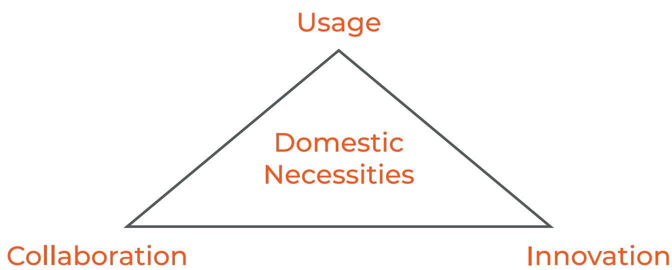
This does not imply to cease all international trade. Exports are needed to maintain global recognition, but we must focus on exporting as OEMs. If we are solely reliant on exporting to foreign OEMs, without domestic usage, we are vulnerable to free trade disruptions (i.e. tariffs). In such a case, where do we look to sell?

Why couldn't Canada's balance of trade recover since the 2008 recession? The days of a healthy trade surplus have not been experienced in over a decade. Our dependence on natural resources as a main driver of exports must be diversified with high technology products, with strategic decision making taking place in our nation.

The underlying message here is to create a change in behaviour, which must be supported by every individual in our workforce, and not simply a few business leaders with a vision. Innovation cannot be forced exclusively through transactional rewards, such as high financial compensation. Creativity is the result of intrinsic motivation and relational rewards, such as recognition from peers and a sense of one's internal worth, beliefs and attitude. Innovation is not a goal; it is a process and a mindset. Performance and productivity for 'knowledge workers' is measured by meaningful work and daily progress. By encouraging domestic usage and collaboration, it will result in high measures of control, curiosity, and recognition within our workforce. This will build Canada's credibility amongst its global trade partners, which will ultimately help in regaining a favourable trade balance.

Kepstrum is the thought leader in deterministic reliability. As a technology provider to parts manufacturers in various industries, our risk- reduction methodology is used to qualify new product developments without history. Our brand is our promise to the Canadian economy: to support and build the adoption for homegrown technologies in the automotive industry.

We have the intellectual capacity and the desire to advance our sector. We have the financial support and the mediums to collaborate. But we need to invest in domestic usage. It is time for a shift.



Siavash Kianpour, B.Comm
Research & Development, Kepstrum Inc.

Payman Kianpour, M.Sc, M.Eng, P. Eng
Director, Kepstrum Inc.

Philip Domingue, B.A.Sc., P.Eng
Project Engineer, Stackpole International

1. Wu, Y. "Homegrown ideas need our support". 2020. Toronto Star
2. Statistics Canada. Table 36-10-0434-03 Gross domestic product (GDP) at basic prices, by industry, annual average (x 1,000,000)
3. Focus2Move. "Global Auto Market. The ranking by manufacturer in 2019". 2020. Focus2Move

APPLICATIONS

• AUTOMOTIVE • AVIATION • INDUSTRIAL
• NUCLEAR • DEFENCE

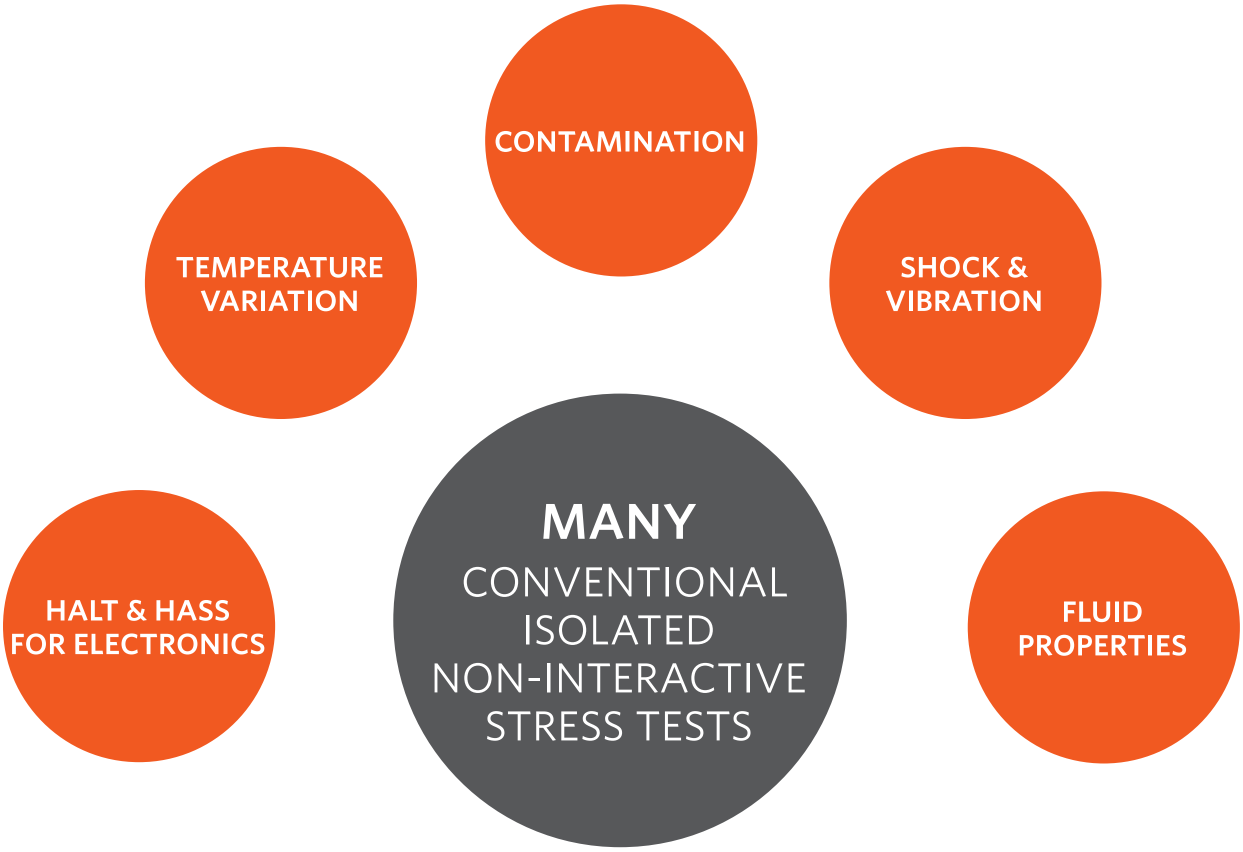
KXC DNA GENERATORS™

MECHATRONICS
HYDROTRONICS
ELECTRONICS
HYDRAULICS
MECHANICAL

PUMPS
VALVES
MOTORS
ACTUATORS
ELECTRONICS
BATTERIES
SOLENOIDS
SENSORS
BEARINGS
SEALS

HOW DO YOU QUALIFY
YOUR NEW DESIGN?

?



with **PARALLEL** TEST BENCHES?

NO STRESS INTERACTIONS
CANNOT REPLICATE FIELD FAILURES

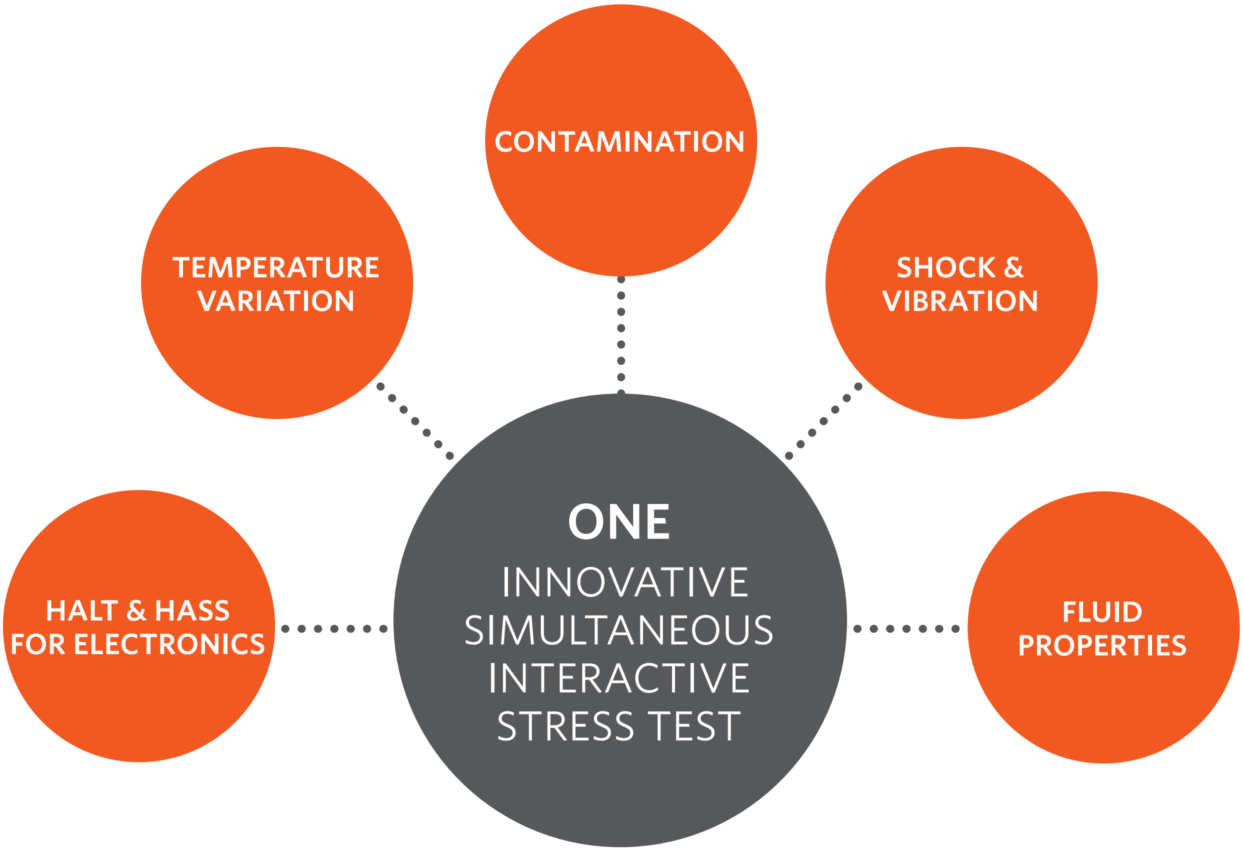
test-to-pass, mainly driven by experience, is not efficient in qualifying the reliability of new and complex components without historical information

TRIAL & ERROR
REWORK
RECALLS

DEMANDING A CHANGE ...

INTELLIGENT RELIABILITY™
IS THE SOLUTION

!



with **KXC DNA** GENERATORS™

ALL STRESS INTERACTIONS CAN REPLICATE FIELD CONDITIONS AND FAILURES

test-to-map replacing uncorrelated test-to-pass producing the
DESIGN LIMIT, **N**ATURE OF FAILURE and **A**CTUAL LIFE
to map the "**PRODUCT DNA**"

MEASURABLE
REPEATABLE
TRACEABLE

SETTING A NEW RELIABILITY NORM ...

KXC TECHNOLOGY

IMAGINE THE REAL-TIME PRODUCT DNA FOR EVERY SAMPLE

with KXC DNA GENERATORS™

- Install the sample
- Upload the Profile
- Map the Product DNA

Simultaneous profiling and control of all Stress-Drivers (interface parameters):

- Fluid contamination
- Fluid properties, temperature and pressure
- Ambient temperature
- Thermal shock
- Mechanical shock
- Mounting vibration
- Driver signals

KXC underlying technologies:

- Simultaneous profiling of all Stress-Drivers to replicate field conditions
- Profile simulator to virtually visualize the field conditions prior to testing
- Simultaneous controlling of all Stress-Drivers to ensure repeatability
- Automated failure criteria monitoring and trending to find the limits
- Advanced sensing, algorithms and analytics to Map Product DNA
- Remote access and monitoring with advanced diagnostics
- Real-Time Product DNA Map display

ALL STRESS INTERACTIONS FOR FIELD REPLICATIONS

CONTAMINATION TESTS

WHY?

IT IS THE LEADING CAUSE OF HYDRAULIC COMPONENT FAILURES!

Contamination under controlled conditions can reveal a multitude of complex failure mechanisms:

1. Validates clearances
2. Verifies tolerance stack-up
3. Reveals mating part interactions
4. Evaluates surface finish quality
5. Measures in-assembly wear properties
6. Accounts for fluid degradation

AN ESSENTIAL PART OF HYDRAULIC TESTING

KXC DIVERSITY IN APPLICATION

REPLICATING FIELD CONDITIONS AND FAILURES

KXC DNA Generators are patented test systems with embedded Intelligent Reliability algorithms to profile contamination, temperature, vibration and fluid properties simultaneously to vary and control the stress interactions. They monitor and trend the product Key Performance Factors (KPFs) and internal stresses to determine the gap to failure and Design Limit.

ALL-IN-ONE RELIABILITY SOLUTION

KXC GLOBAL CONNECTIVITY

PRODUCT DNA - A LANGUAGE WITH NO BARRIERS

KXC provides a common reliability indicator, connecting development and production sites around the world.

- Measurable
- Repeatable
- Traceable

KXC produces the same quality measure globally, making reliable products effortless.

All sites connected with the same **PRODUCT DNA**

KEEP YOUR GLOBAL DEVELOPMENT IN CONTROL

MAP YOUR PRODUCT DNA

DESIGN LIMIT NATURE OF FAILURE ACTUAL LIFE

Real-time DNA Map under simultaneous stress interactions using automated stress and performance trending algorithms

KXC INSPIRATION

Risk Control ...

Replicate real world complexity through controlled simultaneous stress interactions.

Replace meaningless test-to-pass with a deterministic and stress focused test-to-limit to map the Product DNA: limits, failures, life.

Use the Product DNA as the baseline to analyze and respond to every field failure, controlling risk while maintaining your credibility, reliability and profitability.

KXC TECHNOLOGY

Simultaneous stress interactions ...

KXC profiles and controls all Stress-Drivers (interfaces) simultaneously.

KXC triggers internal stress interactions to reveal complex failure mechanisms. It monitors and trends failure criteria to determine the real-time gap to failure.

KXC intelligent algorithms map the Nature of Failure on an X-Y plane, correlating the Design Limit with the Actual Life.

KXC PROMISE

Reduce cost and development time ...

Consolidate and combine your development verification plans to save time and cost.

Replicate complex operating conditions in every test to replace multiple, isolated, non-interactive test plans.

Eliminate the need for additional HALT and HASS equipment and resources.

KXC COMMITMENT

Set a new reliability norm ...

Providing OEMs with an All-in-One solution, to develop and demand the Product DNA in their new LASTENHEFTE and SORs.

Providing OEMs, Tier-ones and part suppliers with a common and repeatable reliability measure and benchmark throughout the product life cycle (R&D, production, field).

Providing research facilities and test labs the means to accelerate learning and follow OEM's demands to map the Product DNA.

Rapid integration with powertrain units

- Electronic & Mechanical Oil Pumps
- Electronic Circuit Boards
- Submerged Solenoids & Actuators
- Seals, Bearings & Sensors
- Flow & Pressure Control Elements
- Engine Oil Seperators and Filters

Fluid type

- Mineral and Synthetic oils
- Engine and Transmission oils

Contamination type

- ISO test dusts: ISO 12103-16
- Non-ferrous powder: <150 µm
- Iron powder: <150 µm
- Synform

Contamination measurement

- Range: ISO 14 to 24
- Particle size: 4 to 150 µm
- Accuracy: ± 0.5 ISO
- Standard of measure: ISO 4406

Special monitoring

- Viscosity, Water content
- Unit Under Test noise level

Stress-Drivers (controlled interfaces)

Simultaneous profiling and closed loop control of interface parameters of an atmospheric oil tank:

- **Contamination:** ISO 18 to 23
- **Ambient Temperature:** -60 to 180°C
- **Fluid Temperature:** -50 to 140°C
- **Fluid Thermal Shock:** +/- 80°C
- **Vibration & Shock:** 3-axis OEM profiles
- **Oil Level:** 50 to 400 mm
- **Air Content:** up to 30%
- **Input signal:** PWM, current, voltage

Failure Criteria (monitored parameters)

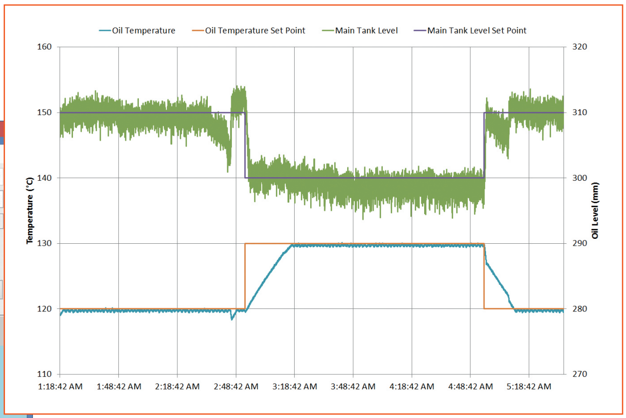
Simultaneous monitoring, measuring, recording and analyzing the failure criteria to determine the real-time gap to failure:

- **Electronics:** temperature, vibration
- **Electrical:** resistance, current, voltage
- **Hydraulics:** leakage, flow, pressure
- **Mechanical:** strain, force, torque, response

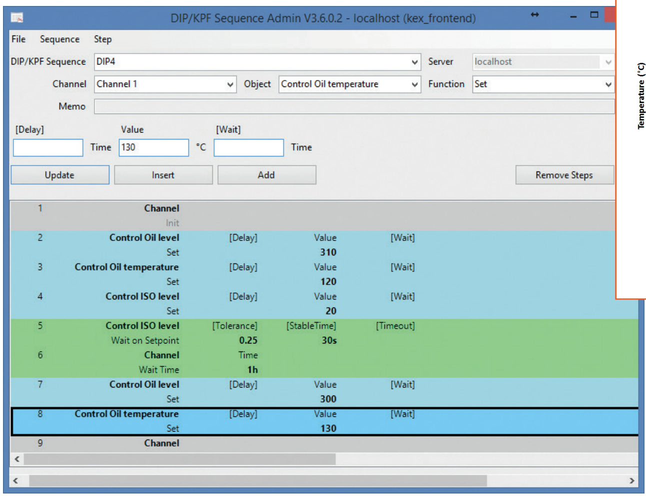
Special interface

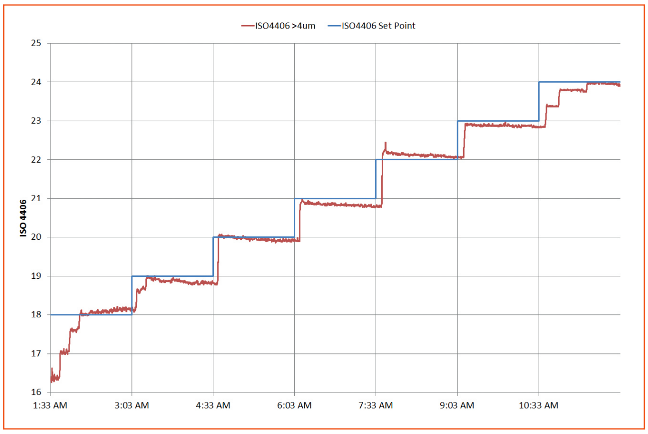
- Soot, Fuel dilution, Fluid properties
- Modal vibration

KXC Closed Loop Adaptive Control
(e.g. Temperature, Level)

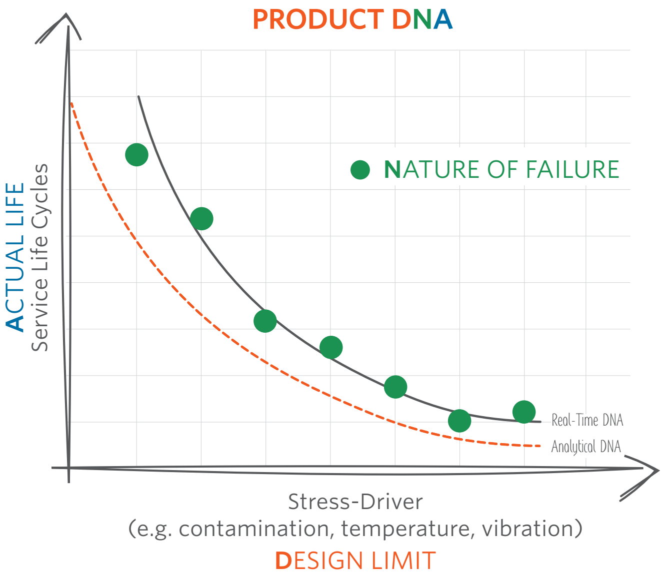


KXC DNA Sequence Profiler (DSP)





KXC Design Limit Test Output
(e.g. Contamination Stress-Driver Profiling)



Design Intent Profile (DIP)

DIP is a user-defined cycle, specifying the Unit Under Test operating conditions.

Design Limit Test (DLT)

DLT is the closed loop controlled Stress-Driver (interface) profiling algorithm.

It is formulated to measure the real-time gap to failure. It automatically adjusts the Stress-Driver setpoints.

The Design Limit and Nature of Failure are generated in a matter of hours.

DNA Sequence Profiler (DSP)

DSP combines DIP and DLT, automating the DNA sequence profiling to map the Product DNA.

- Install the product into KXC
- Upload the DNA Sequence
- Map the Product DNA

Product DNA

Product DNA is generated by an intelligent post processing algorithm operated by DSP.

It analyzes the DLT information to map the Nature of Failure on an X-Y plane, correlating the Design Limit with the Actual Life.

Contamination Stress-Driver technology is the latest controlled interface parameter added to the KXC line of All-in-One qualification units.

KXC Controls Risk to Eliminate Recalls

By using KXC from research to production, you create a repeatable benchmark of product reliability to control risk and eliminate recalls.

KXC is powered by Intelligent Reliability, a proven, stress focused, deterministic methodology to control risk of new designs for high volume production without the need for historical information.

Kepstrum

INVENTOR OF PRODUCT DNA
and KXC DNA GENERATORS™

kepstrum.com
DNAgenerators@kepstrum.com

KxC350hp

DNA GENERATOR™
POWER HYDRAULICS & MECHATRONICS

Rapid integration with hydraulic units
- Flow & Pressure Control Valves
- Seals, Bearings, Hoses & Connectors
- Sensors & Electronics
- Pumps, Motors & Acumulators
- Solenoids & Actuators

Fluid type
- Mineral and Synthetic oils
- Fuel systems (special project)

Contamination type
- ISO test dusts: ISO 12103-16
- Non-ferrous powder: <150 µm
- Iron powder: <150 µm

Contamination measurement
- Range: ISO 14 to 24
- Particle size: 4 to 150 µm
- Accuracy: ± 0.5 ISO
- Standard of measure: ISO 4406

Special monitoring
- Unit Under Test noise level

Stress-Drivers (controlled interfaces)
Simultaneous profiling and closed loop control of interface parameters:

- Contamination: ISO 18 to 23
- Ambient Temperature: -60 to 180°C
- Fluid Temperature: -20 to 80°C
- Fluid Thermal Shock: +/- 40°C
- Vibration & Shock: 3-axis OEM profiles
- Pressure: 50 to 350 bar
- Input signal: PWM, current, voltage

Failure Criteria (monitored parameters)
Simultaneous monitoring, measuring, recording and analyzing the failure criteria to determine the real-time gap to failure:

- Electronics: temperature, vibration
- Electrical: resistance, current, voltage
- Hydraulics: leakage, flow, pressure
- Mechanical: strain, force, torque, response

Special interface
- Modal vibration
- Fluid properties

KxC250hp

DNA GENERATOR™
AVIATION HYDRAULICS & MECHATRONICS

Rapid integration with hydraulic units
- Flow & Pressure Control Valves
- Seals, Bearings, Hoses & Connectors
- Sensors & Electronics
- Pumps, Motors & Acumulators
- Solenoids & Actuators

Fluid type
- Aviation oils
- Skydrol

Contamination type
- ISO test dusts: ISO 12103-16
- Non-ferrous powder: <150 µm
- Iron powder: <150 µm
- Synform

Contamination measurement
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- Particle size: 4 to 150 µm
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- Standard of measure: ISO 4406

Special monitoring
- Unit Under Test noise level

Stress-Drivers (controlled interfaces)
Simultaneous profiling and closed loop control of interface parameters:

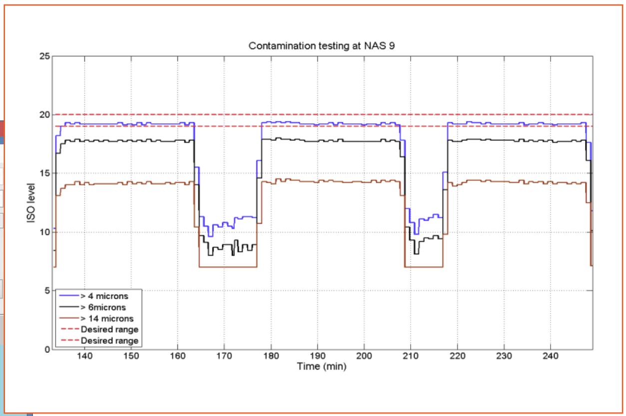
- Contamination: ISO 18 to 23
- Ambient Temperature: -60 to 180°C
- Fluid Temperature: -50 to 80°C
- Fluid Thermal Shock: +/- 50°C
- Vibration & Shock: 3-axis OEM profiles
- Pressure: 50 to 250 bar
- Input signal: PWM, current, voltage

Failure Criteria (monitored parameters)
Simultaneous monitoring, measuring, recording and analyzing the failure criteria to determine the real-time gap to failure:

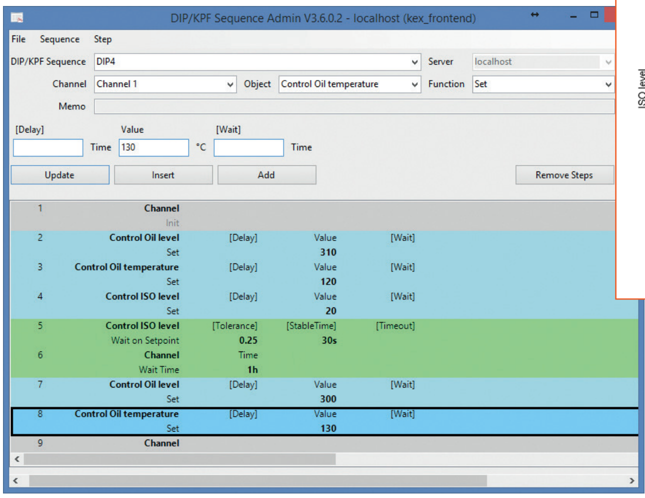
- Electronics: temperature, vibration
- Electrical: resistance, current, voltage
- Hydraulics: leakage, flow, pressure
- Mechanical: strain, force, torque, response

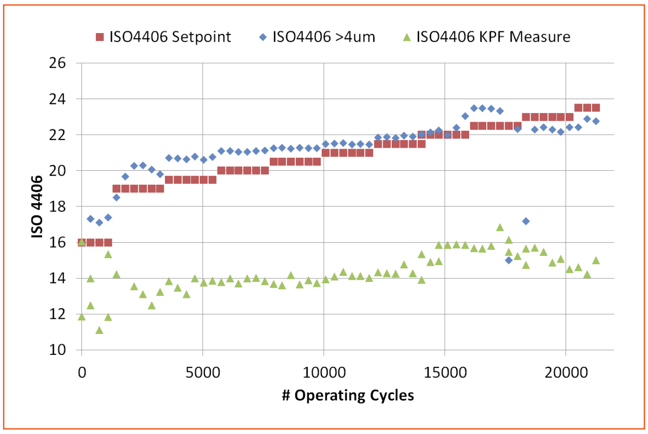
Special interface
- Modal vibration
- Fluid properties

KXC Closed Loop Adaptive Control
(e.g. Contamination)

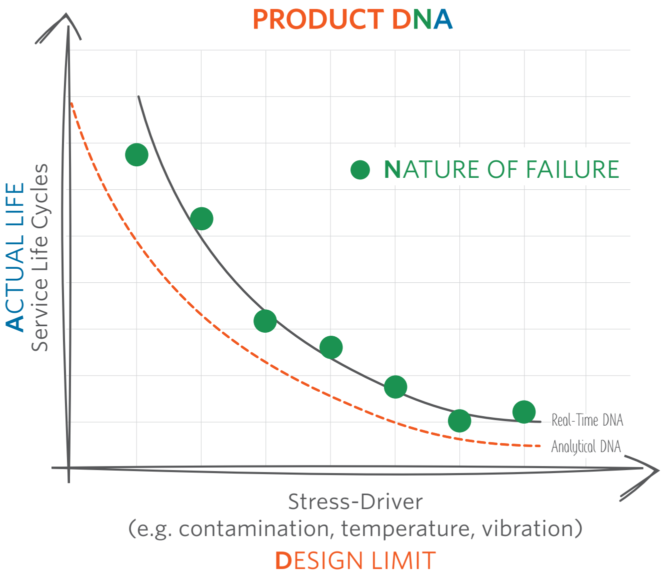


KXC DNA Sequence Profiler (DSP)





KXC Design Limit Test Output
(e.g. Contamination Stress-Driver Profiling)



Design Intent Profile (DIP)

DIP is a user-defined cycle, specifying the Unit Under Test operating conditions.

Design Limit Test (DLT)

DLT is the closed loop controlled Stress-Driver (interface) profiling algorithm.

It is formulated to measure the real-time gap to failure. It automatically adjusts the Stress-Driver setpoints.

The Design Limit and Nature of Failure are generated in a matter of hours.

DNA Sequence Profiler (DSP)

DSP combines DIP and DLT, automating the DNA sequence profiling to map the Product DNA.

- Install the product into KXC
- Upload the DNA Sequence
- Map the Product DNA

Product DNA

Product DNA is generated by an intelligent post processing algorithm operated by DSP.

It analyzes the DLT information to map the Nature of Failure on an X-Y plane, correlating the Design Limit with the Actual Life.

Contamination Stress-Driver technology is the latest controlled interface parameter added to the KXC line of All-in-One qualification units.

KXC Controls Risk to Eliminate Recalls

By using KXC from research to production, you create a repeatable benchmark of product reliability to control risk and eliminate recalls.

KXC is powered by Intelligent Reliability, a proven, stress focused, deterministic methodology to control risk of new designs for high volume production without the need for historical information.

kepstrum.com
DNAgenerators@kepstrum.com

KXC300lp

AN IMPACT IN MODERN RELIABILITY
TO QUALIFY COMPLEX HYDROTRONIC COMPONENTS

DNA GENERATOR™
COOLING SYSTEMS & COMPONENTS

MAP YOUR PRODUCT DNA

DESIGN LIMIT NATURE OF FAILURE ACTUAL LIFE

Real-time DNA Map under simultaneous stress interactions using automated stress and performance trending algorithms

KXC INSPIRATION

Risk Control ...

Replicate real world complexity through controlled simultaneous stress interactions.

Replace meaningless test-to-pass with a deterministic and stress focused test-to-limit to map the Product DNA: limits, failures, life.

Use the Product DNA as the baseline to analyze and respond to every field failure, controlling risk while maintaining your credibility, reliability and profitability.

KXC TECHNOLOGY

Simultaneous stress interactions ...

KXC profiles and controls all Stress-Drivers (interfaces) simultaneously.

KXC triggers internal stress interactions to reveal complex failure mechanisms. It monitors and trends failure criteria to determine the real-time gap to failure.

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Replicate complex operating conditions in every test to replace multiple, isolated, non-interactive test plans.

Eliminate the need for additional HALT and HASS equipment and resources.

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Set a new reliability norm ...

Providing OEMs with an All-in-One solution, to develop and demand the Product DNA in their new LASTENHEFTE and SORs.

Providing OEMs, Tier-ones and part suppliers with a common and repeatable reliability measure and benchmark throughout the product life cycle (R&D, production, field).

Providing research facilities and test labs the means to accelerate learning and follow OEM's demands to map the Product DNA.

Rapid integration with cooling systems

- Electronic & Mechanical Water Pumps
- Thermal Management Modules
- Seals, Bearings, Hoses & Connectors
- Flow & Pressure Control Valves
- Radiators, Heat Exchangers & Gas Tanks
- Electronics & Sensors

Fluid type

- Non-Radioactive Water and Water-Glycol
- Automotive coolant

Contamination type

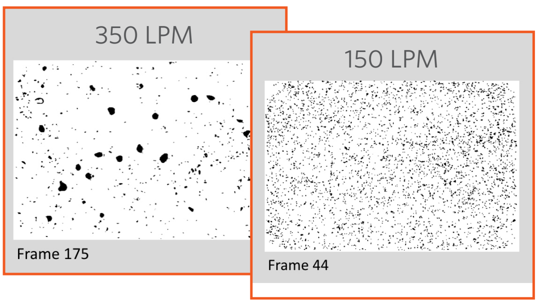
- Sand particles: 0.2 to 2 mm

Contamination control technology

- Particle size, distribution, concentration
- Kepstrum's vision sensor
- Closed loop adaptive control

Special monitoring

- Unit Under Test noise level



Stress-Drivers (controlled interfaces)

Simultaneous profiling and closed loop control of interface parameters:

- **Contamination:** 0.5 to 5 g/L
- **Pressure:** 1 to 10 bar
- **Flow:** 30 to 600 lpm
- **Fluid Temperature:** -50 to 140°C
- **Ambient Temperature:** -60 to 180°C
- **Vibration & Shock:** 3-axis OEM profiles
- **Input signal:** PWM, current, voltage

Failure Criteria (monitored parameters)

Simultaneous monitoring, measuring, recording and analyzing the failure criteria to determine the real-time gap to failure:

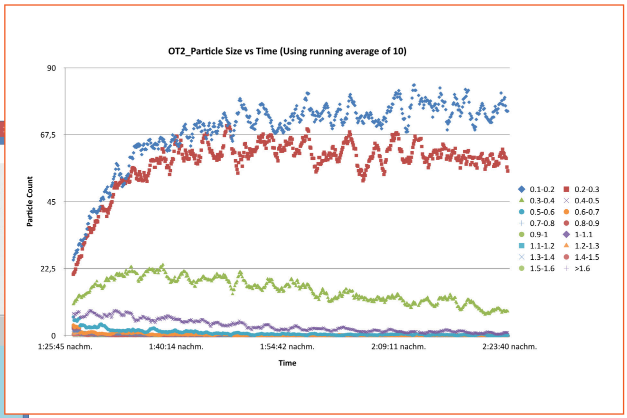
- **Electronics:** temperature, vibration
- **Electrical:** resistance, current, voltage
- **Hydraulics:** leakage, flow, pressure
- **Mechanical:** strain, force, torque, response

Special interface

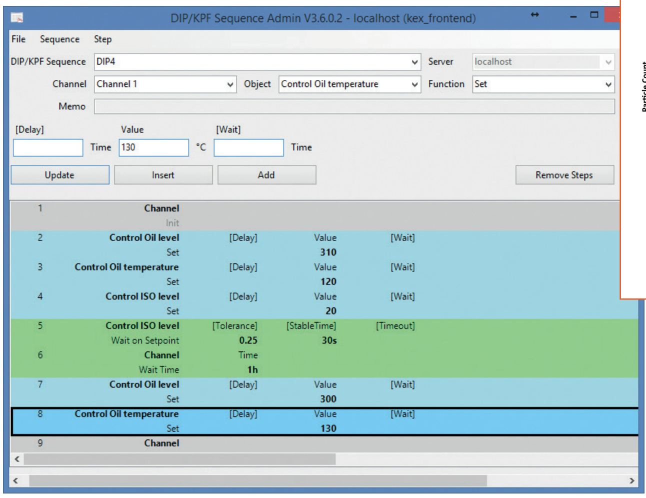
- Modal vibration

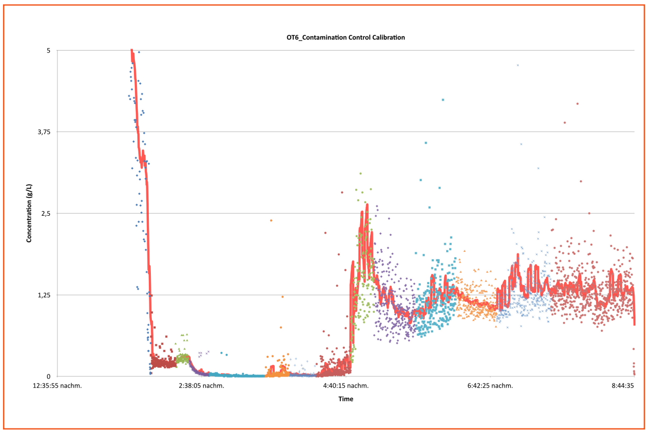
Vision Sensor Output

KXC Closed Loop Adaptive Control
(e.g. Contamination)

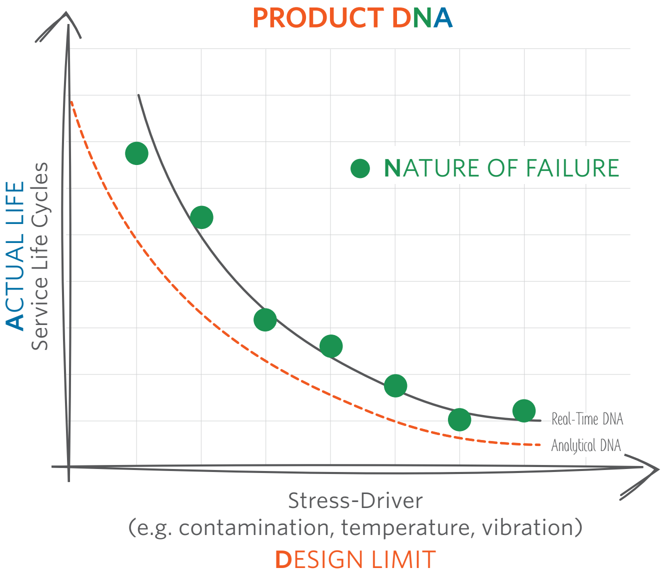


KXC DNA Sequence Profiler (DSP)





KXC Design Limit Test Output
(e.g. Contamination Stress-Driver Profiling)



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Contamination Stress-Driver technology is the latest controlled interface parameter added to the KXC line of All-in-One qualification units.

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By using KXC from research to production, you create a repeatable benchmark of product reliability to control risk and eliminate recalls.

KXC is powered by Intelligent Reliability, a proven, stress focused, deterministic methodology to control risk of new designs for high volume production without the need for historical information.

INVENTOR OF PRODUCT **DNA**
and **KXC DNA** GENERATORS™

kepstrum.com
DNAgenerators@kepstrum.com

CONVENTIONAL
TIER-ONE
DESIGN AND QUALIFICATION

LASTENHEFT (SOR)
based on a single SOR
"Statement of Operational Requirements"

HIGH COST AND LONG LEAD

HIGH RISK OF MISSING FUNCTIONS

TEST STAND DESIGN
SOR based, leading to many early and costly assumptions

HIGH COST ITERATIONS

DESIGN ITERATION
test/statistical based

FMEA AND/OR SIX SIGMA
statistical based failure ranking

HIGH RISK. MANY 1000 HRS & MISSING INTERACTIONS

TEST PROGRAMS
Criteria: Test-to-Pass (series of long tests)
Setup: Performance/Durability based
Measures: Performance only
Interface: Isolated, non-interactive tests

HIGH RISK. CANNOT SOLVE COMPLEX PROBLEMS

TEST TO PASS
cannot connect to the field failures

two years

INTELLIGENT RELIABILITY™ SOLUTION

DESIGN INTENT
Deriving component functionalities and key performance factors from system logic

DESIGN INTENT PROFILE
A unique operating cycle connecting system and component intent

ANALYTICAL DNA
DESIGN LIMIT NATURE OF FAILURE ACTUAL LIFE

Creating the analytical models to identify the key stresses and fix the product weaknesses in the early stages of development. The analytical limits lead to the type and location of instrumentation to set up and calibrate the DNA Generators

REAL-TIME DNA with KXC DNA GENERATORS™
Generating experimental DNA Maps
All-in-One qualification solution accounting for all stress interactions to replicate the real world operating complexity

PRODUCT DNA LIBRARY
KXC maps the Product DNA for the development baseline, engineering changes, new suppliers, cost reduction initiatives and production parts to map the DNA Library. Field failures will be captured by the DNA Library to rapidly determine the root cause with a systematic and deterministic approach

one year

we give you

GLOBAL REALITY

"We cannot solve our problems with the same thinking we used when we created them."
Albert Einstein

1. OEMs map Product DNA
2. OEMs demand Product DNA
3. Part Suppliers map Product DNA
4. Test labs adopt KXC DNA Generators
5. Research facilities map Product DNA to accelerate learning

OEMS SET A NEW RELIABILITY NORM IN THEIR LASTENHEFTE AND SORs
(STATEMENT OF OPERATIONAL REQUIREMENTS)

TO ELIMINATE RECALLS ...

Intelligent Reliability™ provides the forward thinkers and industry leaders with the solutions to qualify their ideas safely and reliably.

IRT™

INTELLIGENT RELIABILITY TECHNOLOGY

A patented, stress focused, risk control methodology, comprising multiple stages of analysis and testing to Map **PRODUCT DNA**:

DESIGN LIMIT
NATURE OF FAILURE
ACTUAL LIFE

Intelligent Reliability reveals product weaknesses and generates design solutions in the early stages of development and prototyping already. It creates a robust connection between development and field, preventing costly recalls.

Intelligent Reliability supports OEMs to generate SORs and LASTENHEFTE. It leads the field in controlling risk for the introduction of new hydrotronic and mechatronic components without historical information.

KXC™

DNA GENERATORS

Patented test systems with embedded Intelligent Reliability algorithms to profile and control the Stress-Drivers (interface parameters) simultaneously. It automatically trends performance and internal stresses to determine the gap to failure.

KXC generates the experimental Product DNA Map against all Stress-Drivers, replicating real world complexity through stress interactions.

KXC DNA GENERATOR is an All-in-One reliability solution. It can be configured to qualify automotive, aviation, industrial, nuclear and defence system components.

KXC provides OEMs, Tier-ones and part suppliers with a common and repeatable reliability benchmark throughout the product life cycle (R&D, production, field).

5 STEPS™

ONE POWERFUL INDEX

A patented process using Intelligent Reliability Technology (IRT) to connect development, production and field through the **PRODUCT DNA**:

DESIGN LIMIT
NATURE OF FAILURE
ACTUAL LIFE

KXC DNA GENERATOR's output maps the product DNA to produce the Intelligent DNA library in 5 critical steps.

1. Design Baseline
2. Production parts
3. Engineering changes and new suppliers
4. Field data
5. DNA library

The DNA LIBRARY maps all possible failure modes and failure mechanisms to correlate the design limit and actual service life using smart analytics.

Product DNA replicates field failures during the development and throughout the production.

This powerful index integrates reliability with the design engineering, qualification testing and production process. It controls risk, reduces cost and eliminates rework and recalls.

It replaces many conventional reliability testing and trending processes to connect global sites at all times.

Kepstrum

INVENTOR OF PRODUCT DNA
and KXC DNA GENERATORS™

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