WHITE PAPER

The Four Degrees of Product Complexity

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INTRODUCTION

The world runs on increasingly complex systems. Organizations face critical challenges in designing, managing, and optimizing these systems for the rapidly changing products of tomorrow. Consumers' connectivity demands are changing at an unprecedented rate, driving companies in every industry to build more complex and more interconnected products and services.

While technology advances make it possible to meet these demands, they do so at the expense of increased complexity for the manufacturer. The growth of electronics and, in particular, embedded software, make cross-discipline collaboration essential. As products become systems of systems, and the amount of electronics and embedded software increases, controlling the variability becomes increasingly complex. The same trends put an increased focus on Systems Engineering and in-service product updates—especially software updates.

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INCREASING PRODUCT COMPLEXITY

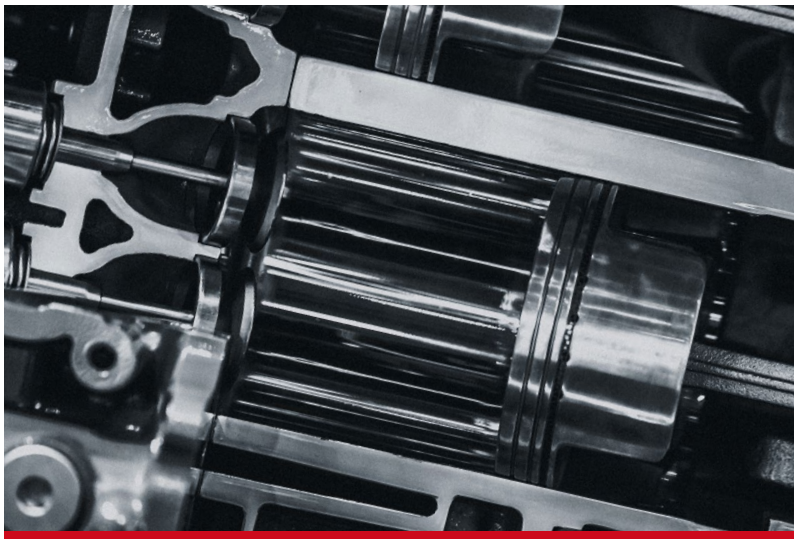
In today's hypercompetitive business environment, future-ready enterprises must be able to better plan and manage their product portfolios, increase the level of commonality, control the variability of their product family, deliver multi-disciplined products throughout the lifecycle, and implement new levels of connectivity to engage and satisfy their customers. Market leaders will have to control this complexity while reducing costs, making better use of high paid resources, increasing their product quality to gain a competitive advantage, all while driving revenue growth and profitability.

COMPLEXITY CHALLENGES

Disparate Tools Reinforce Organizational Silos

Managing complex products throughout the lifecycle is becoming increasingly challenging. Without proper configuration management, variant and option management, and systems engineering, the lack of control and traceability can cause unintended consequences. Errors found late in the process can result in delays, cost of quality issues, expensive rework, inefficient use of resources, liquidated damages, and product recalls.

Today, most companies use separate tools in an attempt to control the complexity of their product development. Many companies think of their Product Lifecycle Management (PLM) systems as the core support for the product lifecycle. But, in reality, these systems are primarily focused on mechanical parts. In addition, there are separate systems used for managing electrical and electronic designs plus Application Lifecycle Management (ALM) systems used to manage embedded software development. Then, various configurators are often used in different groups such as sales/marketing, and engineering without consideration for the optimal process. Where there is a systems engineering effort, tools such as Model-Based Systems Engineering (MBSE) tend to be used in the conceptual phase, disconnected from mainstream engineering and the rest of the enterprise.



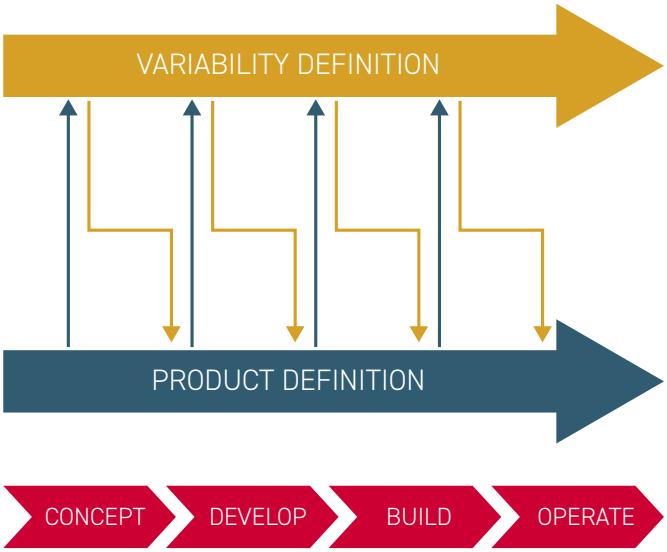
The result is that the flow of product information is often isolated in separate functional data silos, thus creating a fragmented, disconnected process with little to no real traceability back to simulations, quality documentation, etc.

None of this is new, and organizations have been able to keep their processes running, but only by resorting to hundreds of spreadsheets, email, phone calls and ad hoc meetings. But, as product complexity inexorably increases, this duct-tape approach is starting to impact business performance in many ways.

Managing Change and Variation Simultaneously

With this increasing complexity and demand for customization comes the challenge of managing the complexity across diverse product lines, along, with a growing number of product feature variants.

Companies must tackle both the variability and the configuration of the product as both evolve. For example, as the product progresses through its lifecycle, companies need to incorporate changes to the product definition based on some type of effectivity (e.g., date, serial, batch, unit, lot, etc.). When a new variant or option is added, companies need to make sure it resolves to a valid technical solution in the product definition.



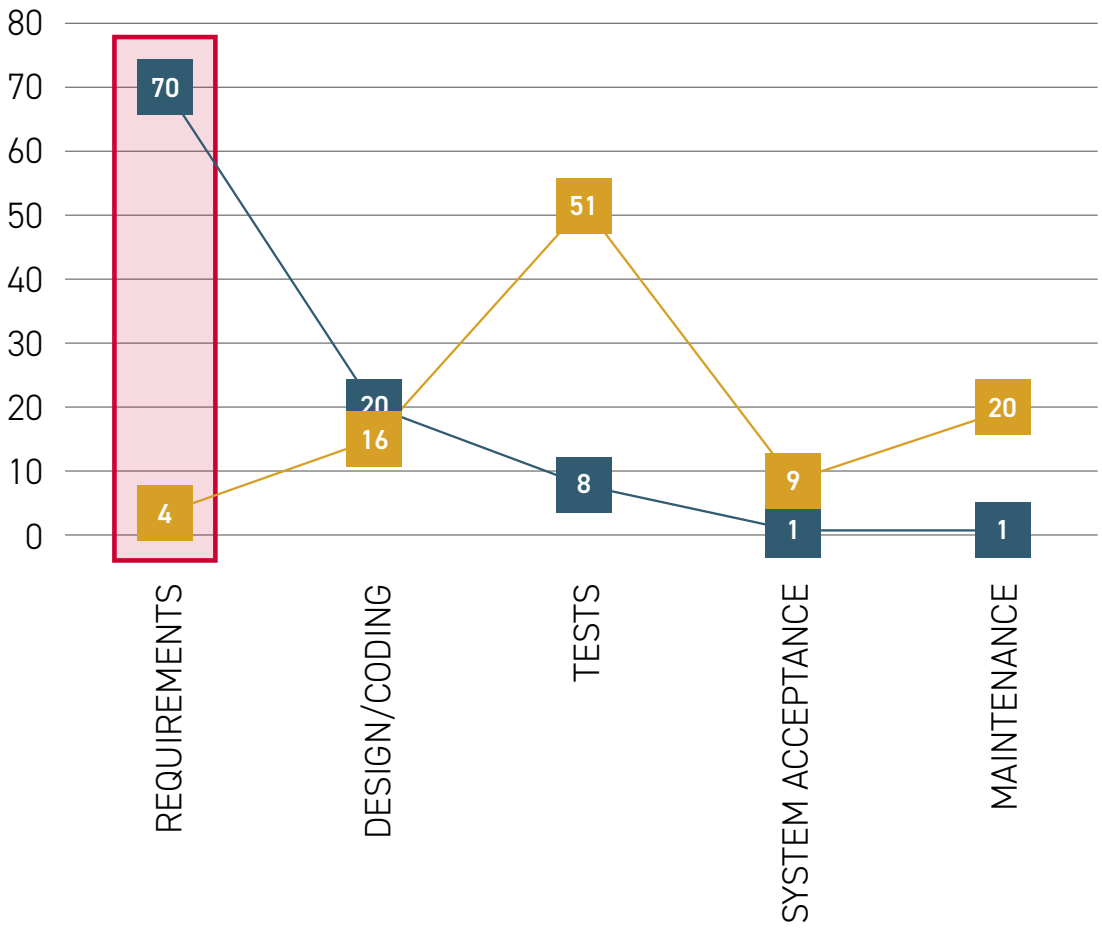
The problem with the traditional approaches to managing variants is that, with the increase in product complexity, there comes an increase in variability that can scale combinatorically with the number of features and rules spiraling out of control.

This is compounded by the complexity of the systems of systems required to handle not only a multidisciplinary product, but all of the different structures that must relate to each other, such as requirements, functions, logical, and physical (RFLP) structures. This gets even more challenging across the product lifecycle, where designing the product, manufacturing the product, testing the product and servicing the product all have different needs.

As an example, let's look at the "Super BOM" concept—also known as the "150% BOM." This refers to a product configuration consisting of all the optional components and modular assemblies needed to generate a 100% configured BOM. As the product definition changes, the configurator, often a separate tool or tools, must be updated, which is time consuming and error prone. Similarly, if a new variant or option is added or changed, it has to be validated technically in the product definition. Attempting to manage variability separate from the product definition can result in unplanned rework, and inefficient use of key resources.

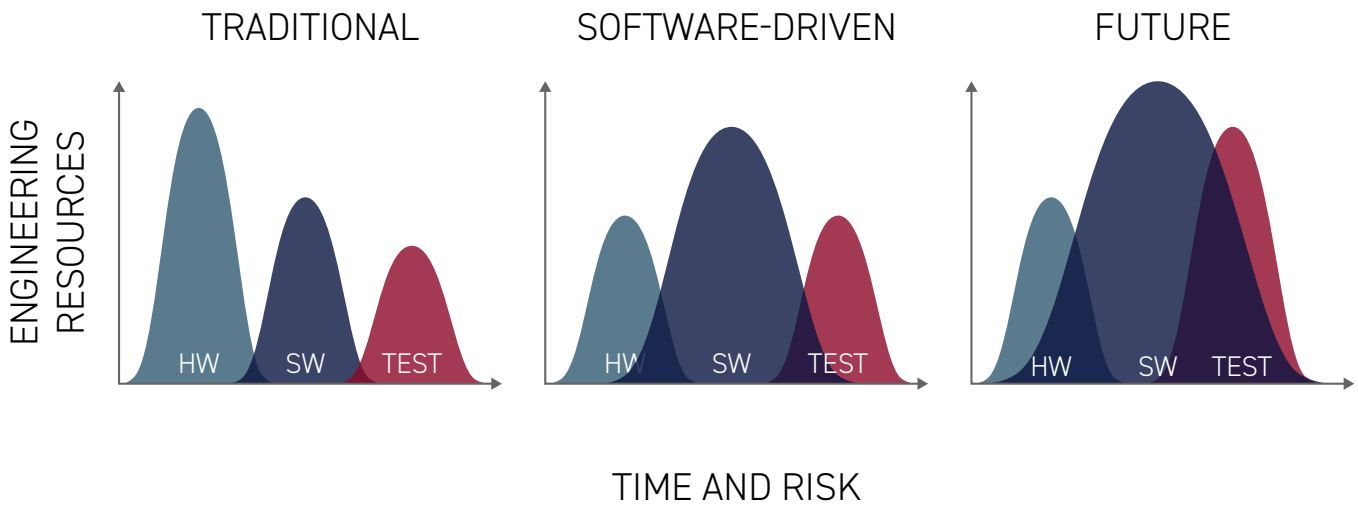
Level of Maturity of Disconnected Systems Architecture

As products increase in complexity, particularly if they are incorporating a significant amount of embedded software, the need for cross-functional Systems Engineering becomes increasingly important. Today, these efforts are usually disconnected from mainstream product development, build and operational phases of the product lifecycle. This results in a large number of errors that are not caught until late in the development process. According to research conducted by IBM, 70% of the errors in embedded systems development occur during the requirements phase, but only 4% are discovered at that stage. Over half are not identified until testing, and one fifth are not found until the product is in service. This slows down development activity, leads to rework, impacts time-to-market and can lead to significant customer dissatisfaction.

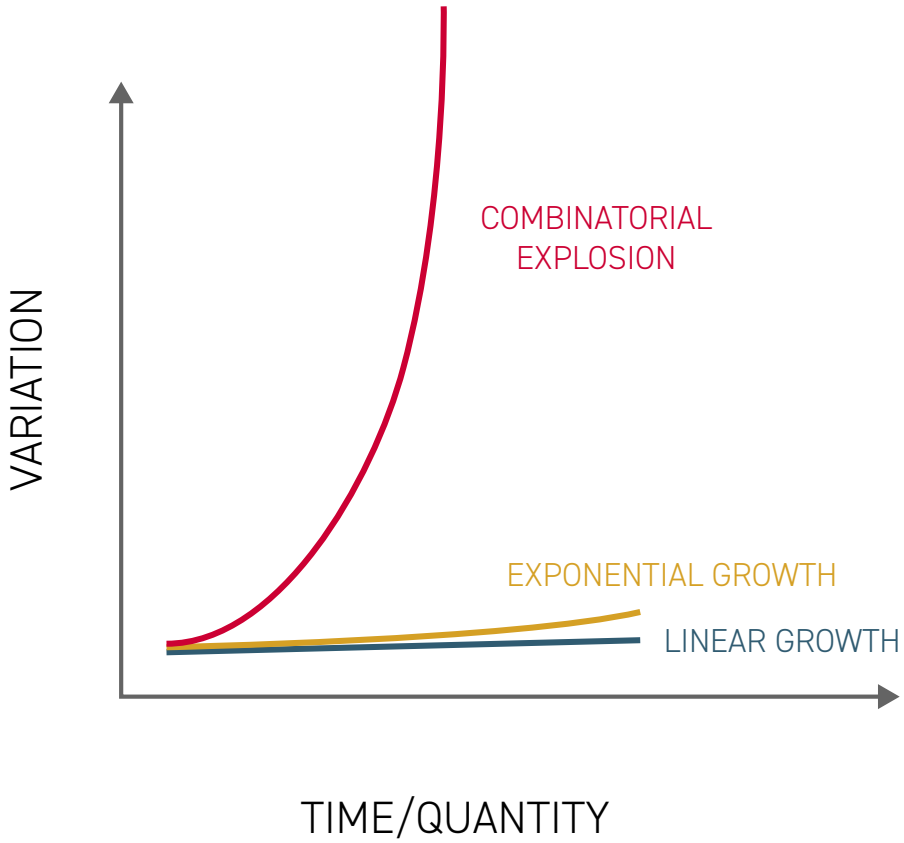


Hardware and Software Challenges

As products become more interconnected, software is no longer an add-on feature, but a critical system in many products, if not the most important differentiator. According to Siegmar Hassis, Daimler, R&D CIO, "80% of Product Innovation and differentiation is now electrical, electronics, and software. Not mechanics." The typical development sequence today is, hardware, followed by software, and then integration testing. Over time, this is not sustainable as more and more of the product and resources are dedicated to software. The trend is clearly toward a convergence of hardware and software overlapping in the product lifecycle as seen in the diagram below.



PLM systems have historically managed mechanical and some electrical parts, while software was managed separately in an ALM system. In practice it has been hard to reconcile the two due to differences such as separate methods for configuration management. But it's clear that, in the future, software will have to be developed concurrently with hardware. And due to the large amount of software, testing will also have to begin before either is completed.



Strategic Reuse

Another challenge impacting manufacturers is implementing a sustainable approach to high level reuse —sometimes called strategic reuse. For example, automotive companies have long used the same platform as the basis for multiple vehicles. Some companies have adopted a product-centric development approach, where each individual product evolves independently from other product lines. This often starts out as a cloned copy of a similar product, and is then modified to fit a new product's requirements. The down side of this approach is that it does not take advantage of commonalities across a product portfolio or platform.

This product-centric development methodology does not scale well. As the number of requisitions or units shipped grows over time, productivity, product quality and the economies of scale in production degrade quickly. The organization then becomes swamped in engineering complexity, risking a dangerous impact on quality and missed innovation opportunities as the organization is forced to allocate more of its key resources toward heroically trying to ship or service ill planned products.

THE WAY FORWARD – A PLATFORM BASED APPROACH

The increase in product complexity is causing global manufacturers to rethink the systems engineering tools and methods used to manage multi-disciplines, the continually accelerating number of product variants, the constantly changing configurations and change throughout the product lifecycle.

The key to reducing these four degrees of complexity is a well-architected system that can manage the configuration of multidisciplinary domains while simultaneously managing the definition of variability once across a portfolio of products, as well as reconcile the change to the product configuration and the features and options of the valid variants throughout the product's lifecycle.

A PLM platform can provide a solution for dealing with these four degrees of complexity by holistically managing the growing complexity of product portfolios, configuration management across multidisciplinary domains, product variants, and change throughout the entire lifecycle.

Systems Engineering

A platform approach enables users to build system models that define the structure, behaviors and fundamental organization of the systems. It does this along with the relationships and behaviors of each of its components to each other and their environment, as well as the guiding principles governing their design and evolution. It allows users to define how systems and subsystems operate, how they are tested and supported, and is designed to be used and accessed by users at all levels of the enterprise, in all disciplines, and throughout all phases of the lifecycle. This complements any Model Based Systems Engineering tools already in place.

Product Line Engineering

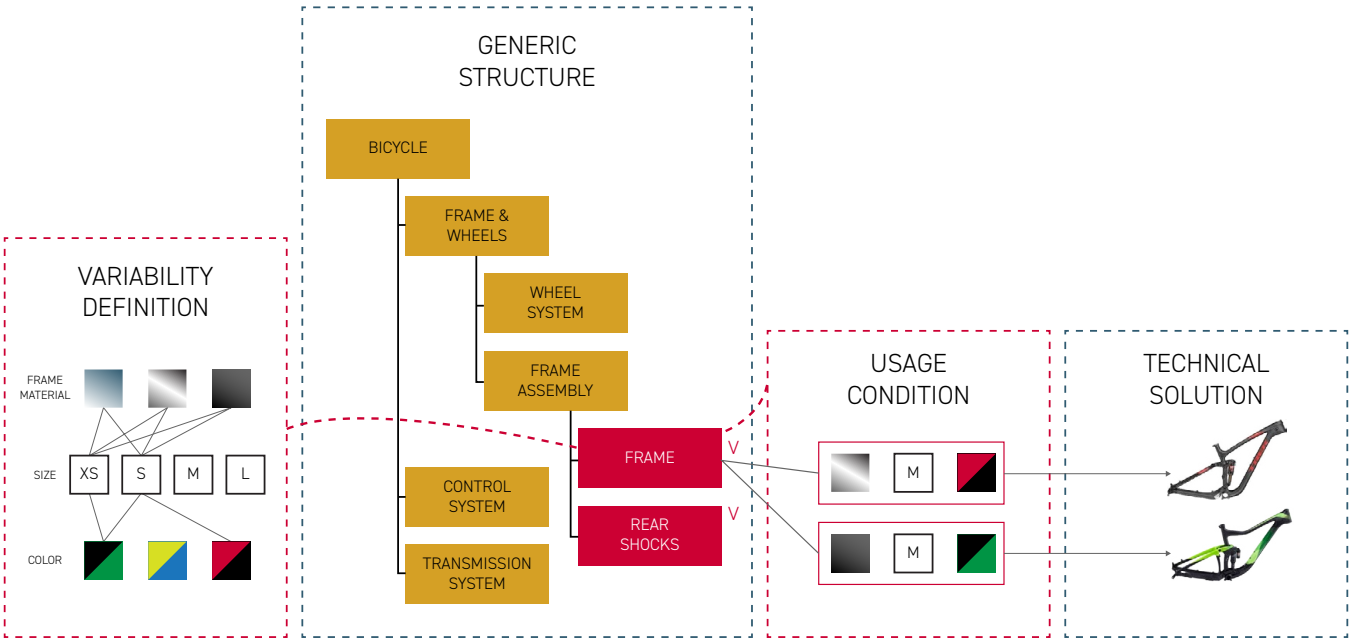
A PLM platform can provide a comprehensive capability that manages strategic reuse across multiple product lines spanning the entire product lifecycle. Sometimes called Product Line Engineering (PLE), the concept centralizes the description of the variation in one place and applies it across a portfolio of products, in a multidisciplinary approach (mechanical, electrical, electronic firmware, and software).

By considering a product line portfolio as a single entity to be managed, as opposed to a multitude of separate products, the platform enables organizations to create, maintain, and evolve an entire portfolio, through each stage of the lifecycle, with a much higher degree of efficiency than has previously been possible. It focuses on the process of enhancing the commonality of new structures by applying control over variability.

Variant (Feature) Management

By employing a PLM Platform, manufacturers can implement a common approach to variability with variants, options and rules, which can be applied to a variety of structures across multiple disciplines to meet a variety of customer needs.

This approach provides organizations with the flexibility to support different needs and outcomes. It controls the variability of the Super BOM and the complexity of the product, now under change management and effectivity control. This includes handling multiple disciplines, such as mechanical, electrical, electronics, and embedded software components, across the product lifecycle.

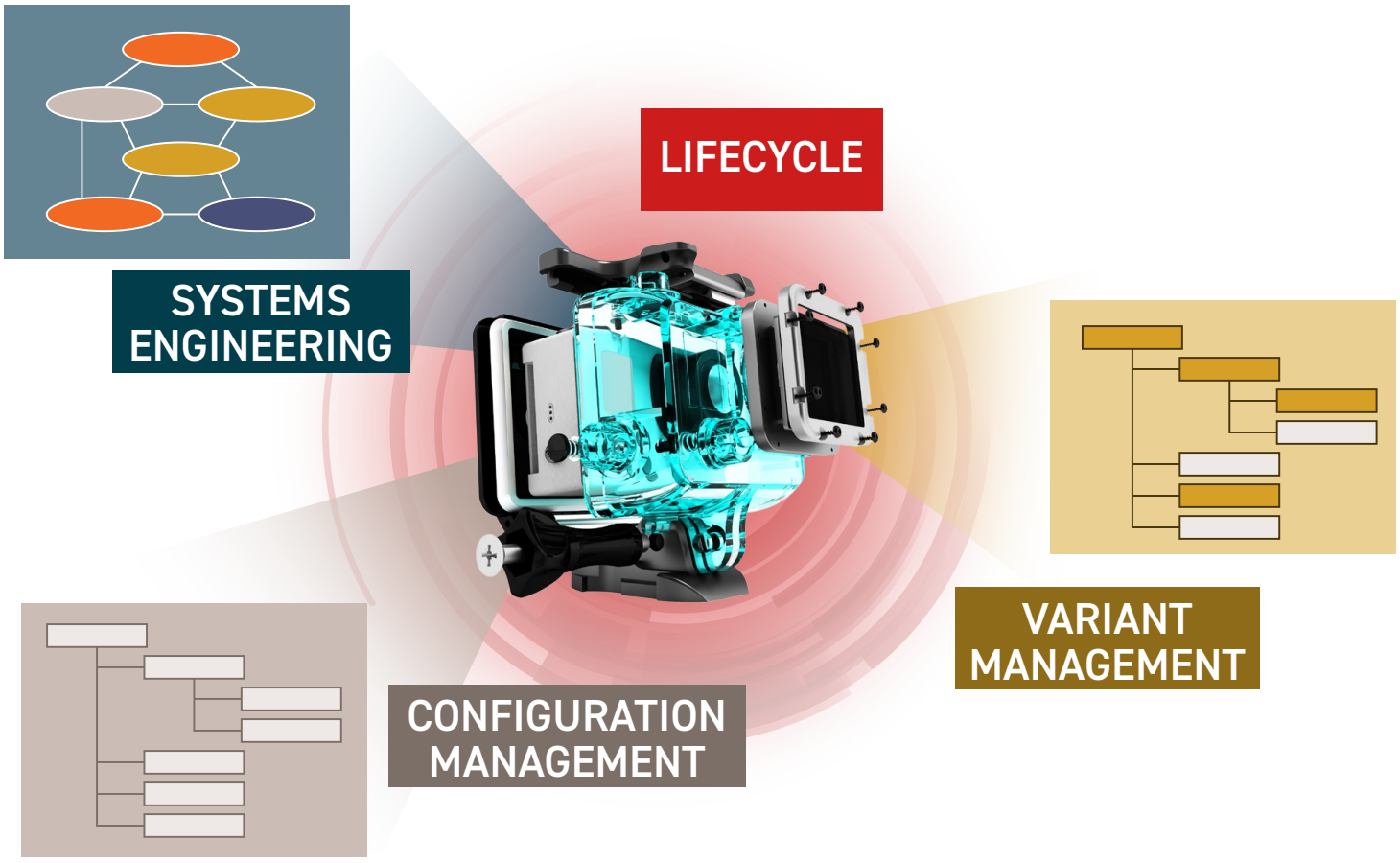


THE ARAS PLM PLATFORM ADVANTAGE

For years, PLM deployments have been limited by being little more than engineering-centric PDM systems. But by taking a radically different platform-based approach, combining support for systems engineering, configuration management across multiple disciplines, and configurator services and applying these capabilities across the lifecycle, Aras has delivered flexible solutions that tackle the toughest complexities facing companies today.

The Aras PLM Platform provides a complete end-to-end lifecycle management system:

- it controls the changes associated with multidisciplinary items in multiple structures from ideation/concept through end-of-life
- it provides a Digital Thread that works both forward as the product progresses and backward, providing traceability to all of the connected multidisciplinary items from structures like RFLP and associated simulations, test and quality documents, etc.
- it provides systems engineering support, not only in the conceptual stage, but at any time in the course of the product's lifecycle
- it supports a variety of variant and option use cases that facilitate systems engineering, marketing, product line engineering, product engineering, manufacturing and services.



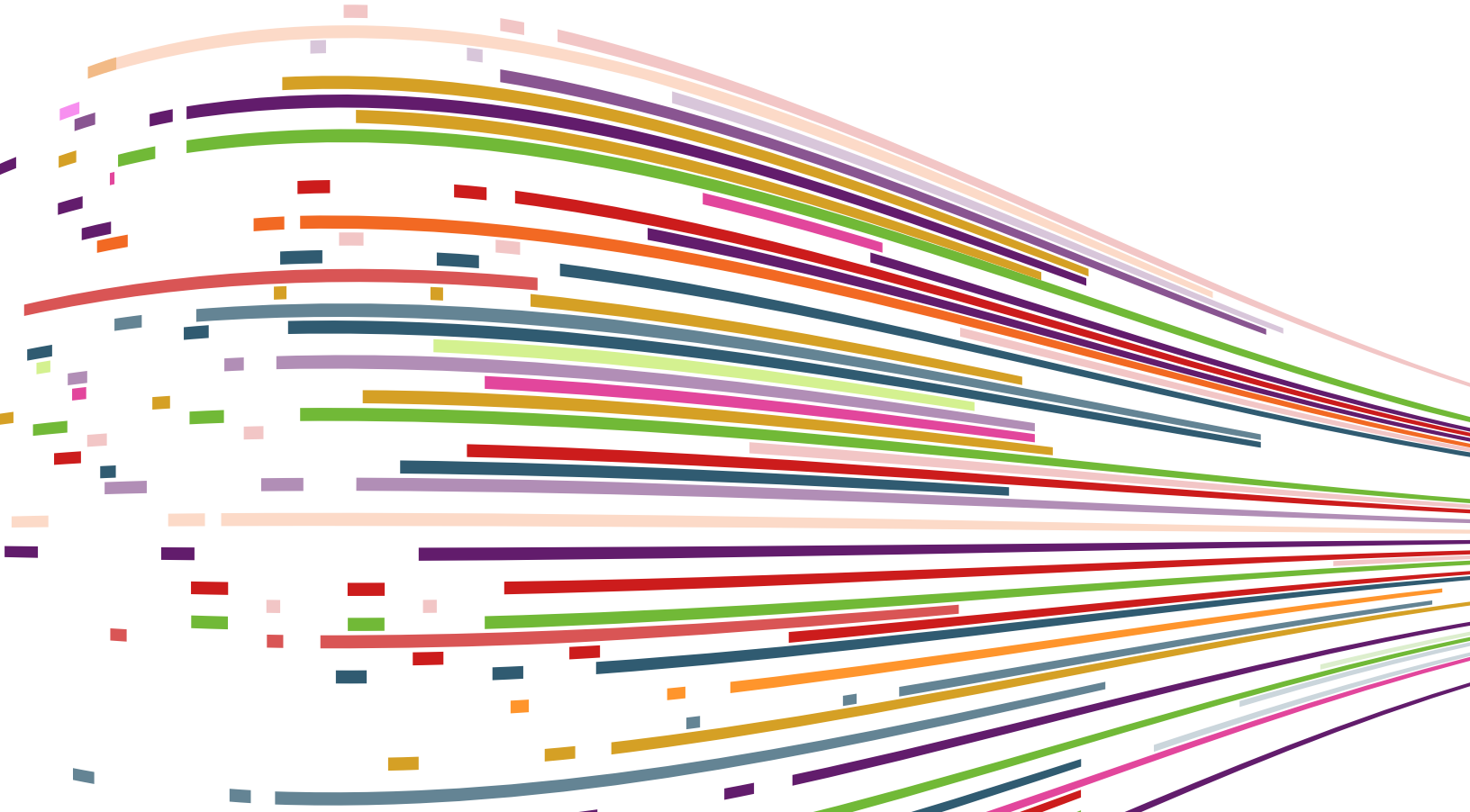
Benefits

The Aras PLM Platform addresses the four major problems companies face due to growing complexity of their products:

- the ability to apply systems engineering to multidisciplinary domains including embedded software
- managing the variants of product portfolios and technical details in one place
- the ability to manage configuration and change management, and
- to do all of this from concept/ideation to disposal across the extended enterprise

Incorporating integrated services inside the Aras PLM Platform is a paradigm shift away from using multiple, disconnected systems through the product lifecycle. It enables organizations to manage the complexity of their products across the product lifecycle and lays the ground work for accelerating innovation to gain a competitive advantage.

By providing an open, flexible PLM platform, Aras addresses the four degrees of complexity. This empowers companies to achieve their digital transformation goals by bringing more complex, innovative products to market faster at reduced costs, with greater quality and operational efficiency, making better use of their high paid resources, driving revenue growth and profitability.



Aras enables the world's leading manufacturers of complex, connected products to transform their product lifecycle processes and gain a competitive edge. Aras' open, flexible, scalable, and upgradeable PLM platform and applications connect users in all disciplines and functions to critical product information and processes across the extended enterprise. Aras customers include Airbus, BAE Systems, GE, GM, Hitachi, Honda, Kawasaki Heavy Industries, and Microsoft.

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