

# Supporting MBSE with Enterprise Digital Threads

*Facilitate digital thread development & maintenance with SBE Vision's platform*

## Takeaways

Digital threads enable sharing stable configurations of product artifacts throughout the product's lifecycle.

Ontologies are critical to defining the semantic foundation for meaningful digital threads that support products' systems of systems.

Developing viable and extensible ontologies for product development leading to long-lived digital threads is a difficult undertaking unless facilitated by experience-based guidance and tools.

Digital threads have impact across the full product lifecycle of tools and information so SBE Vision's adaptive framework is essential for providing digital threads that support the full product lifecycle.

Model-Based Systems Engineering (MBSE) helps companies achieve superior products quickly and with fewer issues and flaws.

SBE Vision's architecture supports development of digital threads regardless of a company's specific information and development tools environment.

## Introduction

The digital thread promises compelling benefits throughout product lifecycles from conception through end of life. Companies are embracing digital thread concepts as part of their product development lifecycle support workflows of products.<sup>1</sup>

Many product-related decisions documented and exposed during product development, deployment, and operation, are critical to determining a company's long-term success. The digital thread supports decisions around design including concept development, systems architecture, and simulation and analysis—*decisions that are made long before even a single part exists*. The digital thread also be employed to determine impacts beyond design, like those pertaining to safety margins, compliance, performance, and finances. These influence when and how operational decisions are made. A safety margin example is crash worthiness for automobiles, aircraft, and other products. Decisions about safety margin first and

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<sup>1</sup> Research for this commentary was partially supported by SBE Vision.

foremost focus on protecting product users. Performance drives sales—whether it is longevity, range and speed, passenger capacity, or energy consumption. For instance, a lighter car or aircraft can go further and faster, while a more energy efficient machine in a factory lowers operating costs. Profitable products can only be achieved through a progression of decisions that are heavily influenced by the interactions of requirements linked to the components of the product definition—*the digital thread contains and maintains a multitude of relationships critical to profitability and lifecycle viability.*

Supporting a digital thread allows complex decisions during product development and deployment to be treated as a systems problem. Systems are best designed around a framework of requirements. The problem is to assure that the requirements are fulfilled and not violated throughout the life of a product, from its conception to retirement. Requirements change, which is fine as long as the impact of any change can be easily discerned, those changes can be controlled, are fit for purpose, then managed through the lifecycle. It is one thing to define requirements before a product is designed and built, but after a product is partially defined or enters service new operational issues and upgrades occur, leading to new requirements that were not originally perceived. An important issue is how the system's defining (required) constraints are documented, maintained, traced, adhered to, and managed as the product is placed in use. To do this requires the concept of a digital thread that includes requirements and other product attributes tied to an ever-changing set of digital model artifacts. Digital threads don't simply exist, they have to be created in a managed environment with an understanding of a product's requirements, how those requirements form the basis of the digital product definition, and how the digital thread transforms over time. SBE Vision provides methods to solve the difficult problems of getting from product requirements to a sustainable digital thread that can drive complex, evolving systems of systems.

## Digital Threads Enhance Systems Engineering

While systems engineering (SE) has been used for decades, digital systems engineering provides digital threads to improve meeting overall product requirements because the threads allow designers to see more clearly how solutions fulfill requirements before a product is produced.

Systems engineering modelling languages allow designers to define fundamental relationships in designs, including physical and logical interactions. Not all systems engineering modeling languages result in digital threads that achieve the desired outcomes of systems modeling including:

- Higher system viability and conformance, due to better integration of reliability considerations into design on a real-time basis (i.e., DFMEA)
- Opportunities to better integrate the thread from product design through design of the manufacturing systems, supporting improved, lower cost production
- Extend the digital thread to support development of maintenance systems, resulting in improved service and lower lifecycle costs
- Improved understandability of designs by others, reducing lifecycle costs

The digital thread supports relationships among requirements and systems architectures, models, and design implementations to document and link these throughout the system's lifecycle.

## The Thread of Requirements Assists Decision Making

A PLM platform provides a framework of openness and services, coming from many innovative sources and provides an architecture for PLM-enabling tools and services. Within that platform, services for grouping and linking related sets of objects to make the best decisions is required.

While the effort required to create requirements, share them among tools, allocate them appropriately, and maintain their traceability has been reduced, the substantial workload required to maintain these links discourages many from continuing to leverage their requirements throughout a product's lifecycle, reducing their value, opening the possibility for errors, and ultimately negating an essential factor for maintaining the digital thread. Yet, as system complexity and the number of artifacts increases, poor requirements management, especially supporting traceability throughout the lifecycle, becomes a company's Achilles heel.

What is needed is in-context viewing and exploration to improve decision making. With a live, active, and connected ontology (see below) and best in class applications, sharing requirements linked to product elements (parts, components, assemblies, etc.) creates stable configurations, which is critical.

An ontology is critical to defining and maintaining requirements traceability throughout a digital thread. A well-developed ontology provides a precise definition of objects, their taxonomy, relationships, attributes, and related knowledge in a required context or configuration. When defined correctly, a product and process ontology will effectively define and manage the definitions of an enterprise's products. It is important that solutions (such as the components of PLM) share a single ontology that enables the exchange and sharing of knowledge among applications. This supports better decisions. Because the ontology acts as an application language broker, a Rosetta stone, enabling sharing of elements from different requirements authoring and management domains as shown in Figure 1, below.

There are many purposes related to developing an ontology that defines digital threads:<sup>2</sup>

- Enables sharing common understandings of the structure of information among people or software solutions
- Enables reuse of domain knowledge
- Explicitly identifies domain assumptions
- Separates domain knowledge from operational knowledge
- Allows analysis of domain knowledge

PLM platforms delivered as Software-as-a-Service (SaaS) or Container-as-a-service (CaaS) have emerged providing a richer ecosystem. Recent CIMdata research has noted the growth of PLM platforms vs. monolithic solutions. But a platform with applications exchanging information is just a start. You also need consistent, repeatable data and process contexts in a stable configuration across these applications.

However, appropriate ontologies to support these platforms are difficult to construct. Partially, this is because teams implementing PLM and systems engineering solutions often do not have access to and experience with appropriate tools and methods for developing viable ontologies. A poorly conceived and implemented ontology is the downfall of many digital thread and system engineering projects. This is an area in which CIMdata believes that the PLM solution providers and system integrators should pursue third-party support.

A product ontology and services help create solutions to support and satisfy requirements, making sure stable configurations are used to exchange knowledge and insights consistently and control changes to these. This enables product teams to manage complex systems of requirements and create a digital thread. The result is that effective product decisions occur faster and change management cycle times and quality improve.

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<sup>2</sup> Noy, Natalya F. and Deborah L. McGuinness . Ontology Development 101: A Guide to Creating Your First Ontology. Stanford University. See: [https://protege.stanford.edu/publications/ontology\\_development/ontology101-noy-mcguinness.html](https://protege.stanford.edu/publications/ontology_development/ontology101-noy-mcguinness.html)

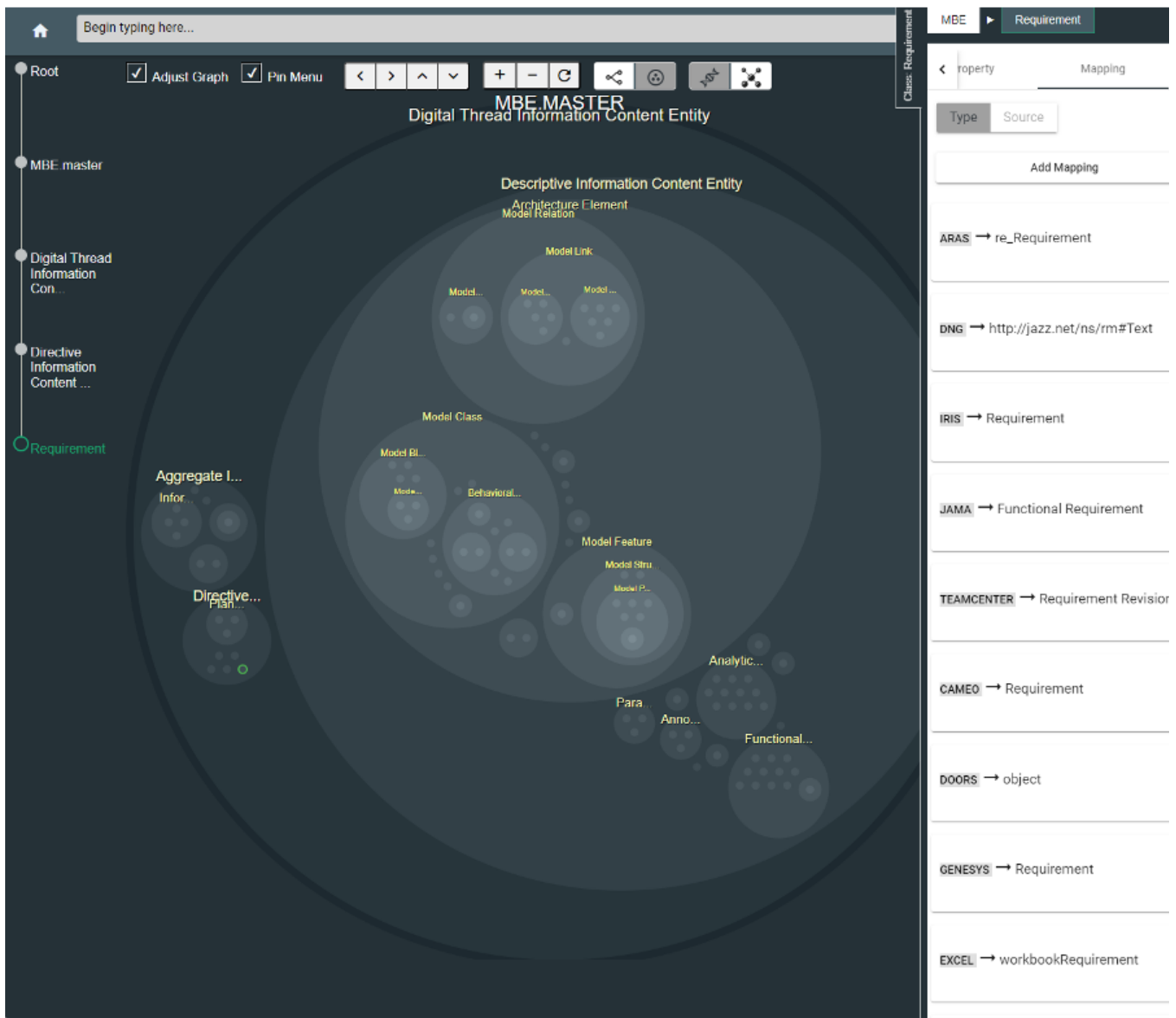


Figure 1—SBE's MBE Ontology Showing Mappings for the Requirement Class  
(Courtesy of SBE Vision)

## SBE Vision's Solution

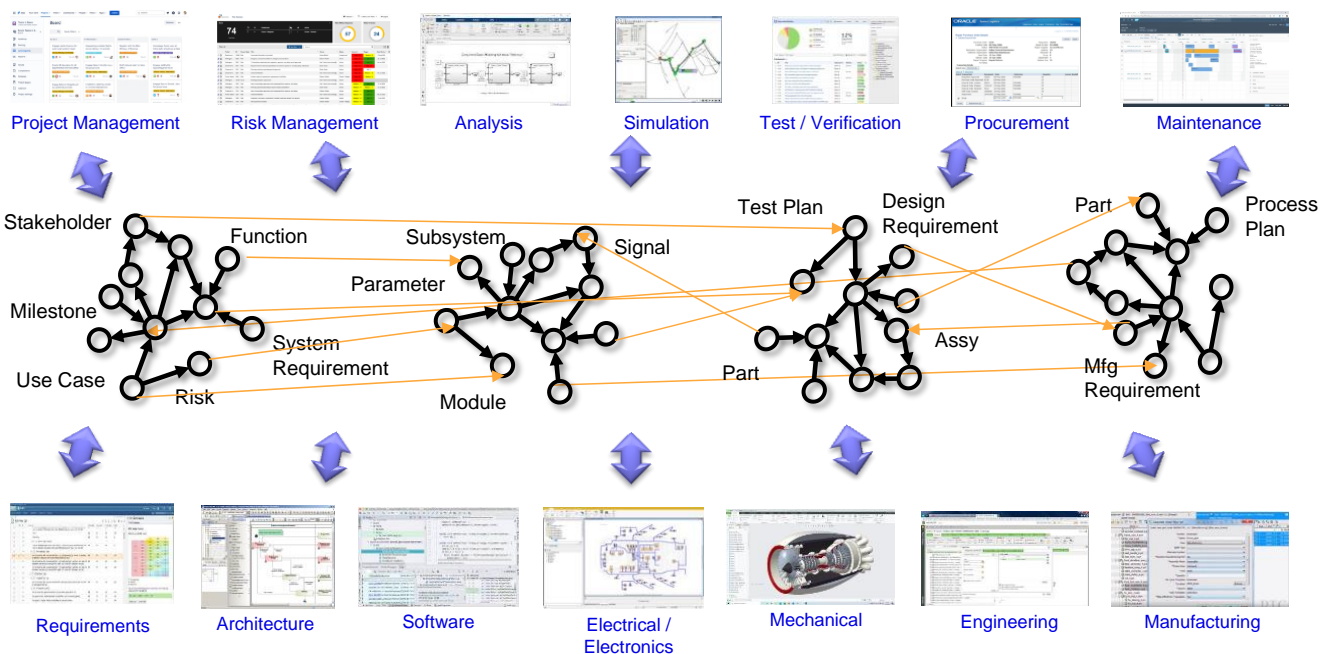
SBE Vision's solution utilizes ontologies to facilitate digital engineering and related activities. It solves many of the pitfalls inherent in achieving a viable digital thread, tying disparate application information and data models together in a hybrid digital thread that can support in-design processes using their data model (ontology).

Persistent URLs support information linking in a viable digital thread across applications. Standards like OSLC and RESTful APIs provide some of the exchange capabilities needed to connect heterogeneous applications. This is critical because it is desirable to use the best requirements management and MBSE applications with the best of an organization's mechanical, electrical, software, simulation, and verification engineering applications, regardless of differences in data structures and formats. To provide a stable context, i.e., support configurations, these applications need a service which can broker communications and data flows among them—similar to how the Internet works in a scalable and secure environment. However, remote linking standards like OSLC have inherent weaknesses: missing contexts, lacking cross-

system search, not providing a consistent user experience, and most importantly, an inability to communicate data states across application boundaries.

Product developers need a persistent set of data and services that inform a digital thread to organize and explore all requirements and systems engineering contexts so that they and their customers and partners can make the best decisions about a product.

Using requirements, architectures, and designs in different perspectives is a key to improving decisions, but they need to be delivered to the ecosystem of consumers in the context of their particular applications. Accomplishing this requires the bi-directional transformation of complex product-related data which effectively can only be achieved via semantic transformation such as that provided by SBE Vision's Semantic Data Broker (see Figure 2). Beyond remote linking, the Semantic Data Broker provides a mechanism for sharing data between applications via a publish and subscribe approach, again, based on having a well-defined, complete ontology. This technology delivers a highly configurable synchronization capability that supplements remote linking to allow digital threads to be constructed through either means, both local and remote linking. In SBE Vision's data broker, every object on the digital thread is an OSLC resource that is OSLC-GC (global configuration management) aware. SBE has synthesized this remote linking technology with its publish/subscribe technology in a seamless way.



**Figure 2—SBE Vision Provides the Basis for a Semantic Data Broker**  
(Courtesy of SBE Vision)

SBE Vision continues to develop a solution platform to define and support requirements, models, and verification management in a heterogenous authoring and usage environment. Integrations with DOORS Next, Teamcenter, Windchill, a variety of MBSE and analysis tools such as Cameo, ModelCenter, Rhapsody, Genesys, Simulink, Jama, Jira, and others assures support across environments. SBE's solution is ontology-centric. It uses a semantic ontology as the universal language by which systems share data. It is based on open ontologies where users of any engineering tool can work in their preferred system and can examine requirements or models authored and managed in foreign systems. This includes support for industry standard ontologies such as the Basic Formal Ontology (BFO).<sup>3</sup> SBE's Semantic Data Broker provides the

<sup>3</sup> For more information BFO see: <https://www.youtube.com/watch?v=QGmwIwmyJeg&list=PLyngZqll3WTgK3qMmOWt4VDIbh-xB3EjK>  
Also see: [https://www.youtube.com/watch?v=Y16\\_M1sQEAQ](https://www.youtube.com/watch?v=Y16_M1sQEAQ)

essential link to the plethora of tools in use today to support digital threads. SBE also has vast experience creating ontologies for their clients.

SBE Vision's platform technology helps create and maintain traceability across requirements and model management tools, and establish and share *stable views*, that is, configurations or contexts. These requirements contexts can be coherently examined and modified, even when they come from different requirements authoring systems, thus enabling digital threads. This allows systems engineers to provide views across stable digital thread contexts, thus improving decisions. These stable configurations can link any elements of information, such as parts and assemblies, in a PLM ecosystem, not just requirements.

Digital thread visualization is a serious problem when models have hundreds of thousands of nodes. SBE's approach is to focus on task-specific dashboards, reporting, and analytics that provide answers to important process-specific questions with rapid response times. This allows users to work in their solutions' UIs, without switching to SBE's.

An adapter strategy is key to a well-functioning digital thread—allowing integration and interoperability across preexisting, often siloed tools and information. SBE's adapter Software Development Kit (SDK) provides critical support for organizations who write their own adapters, which is particularly important in highly-secure environments and whenever IP protection is critical. SBE offers an SDK that allows companies to quickly create their own integrations across the digital thread. Its open architecture has demonstrated numerous engineering tools working together in an effective manner.

SBE-supplied adapters are SBE platform version independent. As such they can be dynamically registered with any version of the SBE platform at any time. It is the SBE Connector SDK that provides this layer of abstraction between the SBE platform and the external Authoritative Source of Truth (ASoT). Once registered with SBE, a new connector can "attach" datasets with the SBE digital thread via a "channel."<sup>4</sup>

SBE is cloud-native and is developed using a scalable container microservices architecture where every digital thread service runs in its own container and thus can be independently scaled as needed. Furthermore, SBE supports hybrid deployments where clusters can be split seamlessly between on-premises and commercial cloud nodes.

SBE's publish-subscribe-apply refresh capability means that every adapter they provide is bi-directional. SBE can, for instance, publish a Cameo model into PLM, ALM, requirements management, and other tools. Using the SBE UI or APIs, collections of objects from multiple systems can be modified and those changes written out to the ASoTs, thus enabling an entirely new class of use cases where customers can have 3<sup>rd</sup>-party web apps drive custom digital thread apps using SBE as a backbone.

## Summary

To support ever-changing, temporal product information and configurations, manual methods of requirements management to support digital threads must become at least semi-automatic allowing the revelation of knowledge to support insights and adjust requirements rapidly and accurately. The SBE SDK helps build and maintain digital threads, providing long term benefits, even in heterogeneous application environments.

SBE's philosophy is to create plugins to every connected digital thread tool so that nobody has to leave their preferred user interface to use SBE. Ontologies help SBE avoid the  $N^2$  point-to-point solution integration and plugin problem found in many solutions. An ontology builder is part of the SBE solution—and importantly part of their service methodology. Building a solid ontology provides the underlying

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<sup>4</sup> A bi-directional pipeline for the communication of digital engineering data between and authoritative source of truth (ASoT) and the digital thread

foundation for a successful digital thread and MBSE strategy. SBE Vision has many years of experience augmented by tools that support this critical ontology foundation. SBE's task-specific dashboards, reporting, and analytics allow users to stay in their familiar UIs. SBE also provides integrations to many reporting and analytics and visualization platforms.

Industrial companies and government organizations are using SBE's technology, and CIMdata expects that use to grow. Rapid product innovations occur in a PLM ecosystem, which also fosters process and application innovations. SBE Vision provides capabilities that other digital thread solutions fail to offer—defining requirements in a neutral ontology, while offering many MBSE tool integrations, allowing digital threads that use a company's current, favorite solutions and data.

If you are trying to create a viable ontology and build a digital thread foundation, consider evaluating SBE's solution.

## About CIMdata

CIMdata, a global, independent strategic management consulting firm, provides services designed to maximize an enterprise's ability to design, deliver, and support innovative products and services. For more than forty years, CIMdata has provided industrial organizations, providers of digital technologies and services, and investment firms with world-class insight, expertise, and best-practice methods on a broad set of product lifecycle management (PLM) topics and the digital transformation they enable. CIMdata also offers research, subscription services, publications, and education through certificate programs and international conferences. To learn more, visit [www.CIMdata.com](http://www.CIMdata.com) or email [info@CIMdata.com](mailto:info@CIMdata.com).