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► **To cite this version:**

Purnima Rao, Kandhasami Palaniappan. Continuous Engineering Through ALM-PLM Integration. 17th IFIP International Conference on Product Lifecycle Management (PLM), Jul 2020, Rapperswil, Switzerland. pp.798-811, 10.1007/978-3-030-62807-9\_62 . hal-03753135

**HAL Id: hal-03753135**

**<https://inria.hal.science/hal-03753135>**

Submitted on 17 Aug 2022

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## Continuous Engineering through ALM\* -PLM\*\* Integration

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**Abstract.** “A techno-domain-driven approach will in all likelihood revolutionize how a product development organization resonates with changing end-user demands and, its vendors in a collaborated and continuous engineering setup, and thereby driving transformational change.”

The increasing convergence of markets and smart products, shifting business models as well as increased customer expectations have created an unprecedented level of complexity for product development organizations. Particularly, in the automotive industry, complexity has literally exploded in the four dimensions of **product, processes, tools** and **compliance**. Thereby, product development organizations are under tremendous stress to adopt stringent processes thus, leading to complex tools usage to meet the target compliance. In order to be in a position to cope with this dilemma of new complexity and to safeguard sustainable competitiveness, it is vital for organizations to implement an integrated, holistic approach to manage the different dimensions of product development. As current product development involves hardware, electrical & mechanical (PLM) components and software components (ALM), their respective lifecycle management processes also throw challenges of coordinated and continuous engineering. This means we need a paradigm shift from the traditional practice of disparate lifecycle management to an innovative concept like **Sleek Lifecycle Integration & Management (SLIM)**.

**Keywords:** Lifecycle, Integration, ALM, PLM, Exchange, Synchronization, Traceability, disparate systems, continuous engineering, connected automation, lean lifecycle management, lean lifecycle integration

## 1 Preface

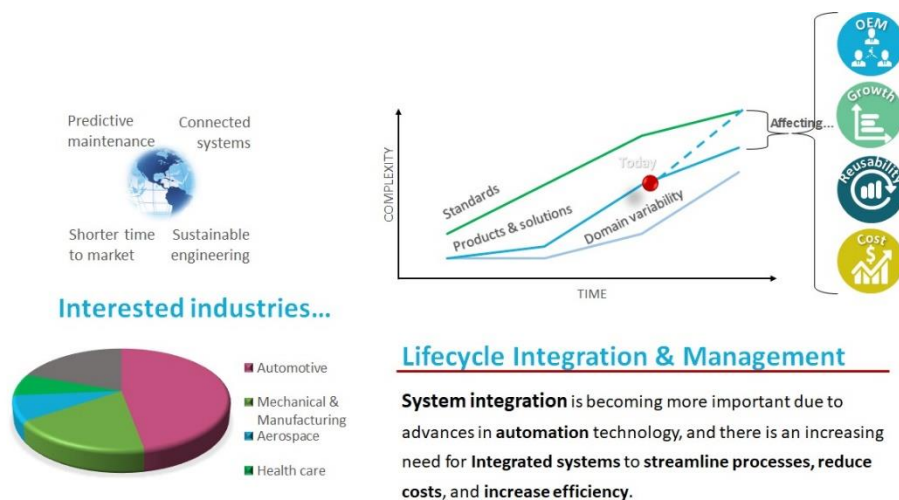
Studies in the recent past indicate that organizations are serious about software and technology as their products are worthwhile only if it is smart. Smart products comprise

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\* Application Lifecycle Management

\*\* Product Lifecycle Management

not just HW<sup>1</sup>, but also embedded SW<sup>2</sup>. This indicates that the integration of disparate HW and SW lifecycles becomes the core essential in product development. Added to this, market expectations are value for money, shorter launch cycles, etc. This means cost of engineering and predictive maintenance too become essential for the organizations to keep their product costs competitive.



**Fig. 1.** Author's derivation based on the pulse of industries and market

#### SNIPPET

**As per the market study by independent blogger Mr. Oleg Shilovitsky, smaller companies are better and faster in adopting the digital thread. Most of these companies are “digital native<sup>1</sup>” and they have urgent needs in solutions capable to connect engineering and downstream processes. The need of the hour for them is to have quick deployable engineering solutions (targeting the core engineering functions).**

We see that software and technology is a critical element, and it is important to know what they comprise. Software and technology comprise tools, solutions, domain and standards. The core challenges of industries will resolve when standards, technology (products & solutions) and domain variability converge at some point. Otherwise, the gap will continue to affect OEM-supplier integration, growth of the organization, cost of engineering and reusability. Hence, lifecycle integration & management become core mantra going forward.

<sup>1</sup> Hardware

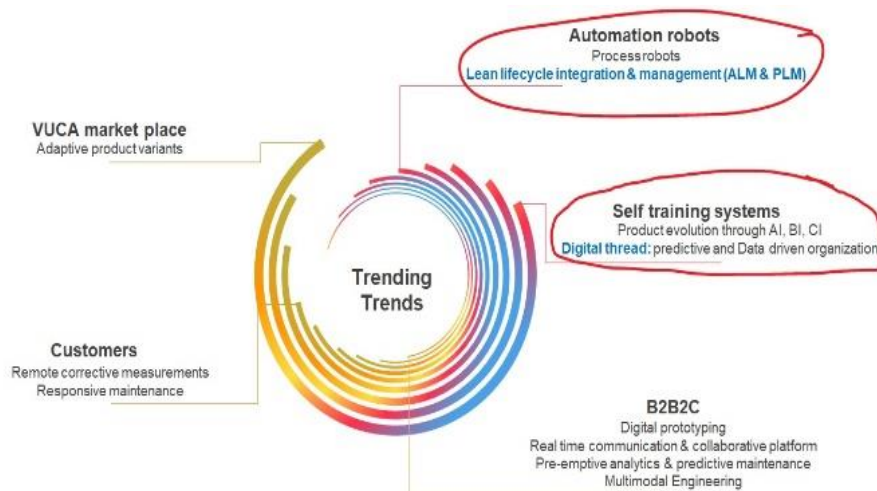
<sup>2</sup> Software

The core essential problem is integrating these lifecycles for a coordinated and continuous engineering while solving cross-domain traceability and smart KPI reporting.

“What got us till here, will not take us there; unless, we digitally transform by changing the definition of integration in the world of product engineering”

## 2 Market Trends

The Product development in any industry is continuously evolving. It is all about innovation, being different, getting to market first and keeping up with consumer demand. Additionally, today’s conventional approach of product development is being constantly challenged for its sustenance with new advances in AI and IoT. Below is a snapshot of market trends gathered from different sources.



**Fig. 2.** Author’s perception based on market trends

**Digital Thread** manages the complexity of the product development. A product may have hundreds of individual components or assemblies, some of which the manufacturer may produce and others that are sourced from a range of suppliers (or suppliers’ suppliers). This chain can become incredibly complex to manage, as a single design change can affect the manufacturing of multiple components. By providing a “single version of the truth,” the Digital Thread helps manage this complexity. In a MBE<sup>3</sup>, the

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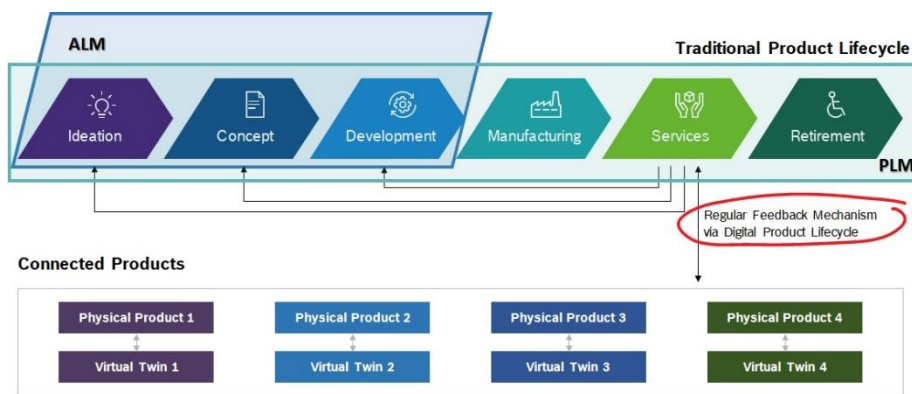
<sup>3</sup> Model Based Enterprise

structured way of handling the information happens via the Digital Thread (such as 3D model, meta-data information for MBM<sup>4</sup>, MBQ<sup>5</sup>, etc.)

In the face of these intricacies, **ALM-PLM<sup>6</sup> is emerging as an innovation platform** that enables the digital thread, providing traceability, agility, and customization. While doing so, it is important to remember the following four major objectives:

- Identifying and incorporating customer needs
- Understanding and improving customer experience (i.e., UX<sup>7</sup>)
- Completely closing the loop in the product design & development (CLLM<sup>8</sup>)
- Infusing the insights from the sample field data collected from connected products

Connected products enable the concept of a closed loop lifecycle and bring the data back to the design and development team. With the data flowing back (to the design teams), the teams will not only be able to run the predictive design but also build smarter products.



**Fig. 3.** Data driven product development involving ALM-PLM (Digital Thread)

### Top Drivers of Digital Thread:

1. Collaboration and better configuration management
2. Unification of software and hardware in the product
3. Product Development and Manufacturing Integration focusing on **traceability of product artifacts<sup>9</sup>**

<sup>4</sup> Model Based Manufacturing

<sup>5</sup> Model Based Quality

<sup>6</sup> ALM & PLM integrated

<sup>7</sup> User eXperience

<sup>8</sup> Closed Loop Lifecycle Management

<sup>9</sup> One of many engineering tangible objects used in product development. Ex: requirement, UML models (use case, class diagrams, etc.), test case, documents, etc.

4. Product lifecycle development & Servitization<sup>10</sup>
5. End of cycle & compliance management
6. Circular economy<sup>11</sup>

#### INSIGHTS

- Overall PLM market has grown by 9.9% to USD 48b in 2018 (including ALM, PLM, and Digital Manufacturing). Share of PLM is USD 16.2b and ALM is USD 5b
- Product data on digital thread<sup>1</sup> & traceability (ALM + PLM + IoT + Digital Twin)
- Adoption of PLM on the cloud with micro services (with DevOps)
- While data is the crude oil, the governance of the data is the key to have a 'refined' oil (Master data governance)
- PLM + Additive Manufacturing
- PLM + Blockchain
- Digital Thread

### 2.1 Driving Forces of an Industry

There could be many drivers or influencers for a business. When broadly classified under major categories, we see three major influencers –

- Customer brand loyalty
- Holding maximum market share
- Being futuristic – adopting technology

These three influencers have a strong correlation.

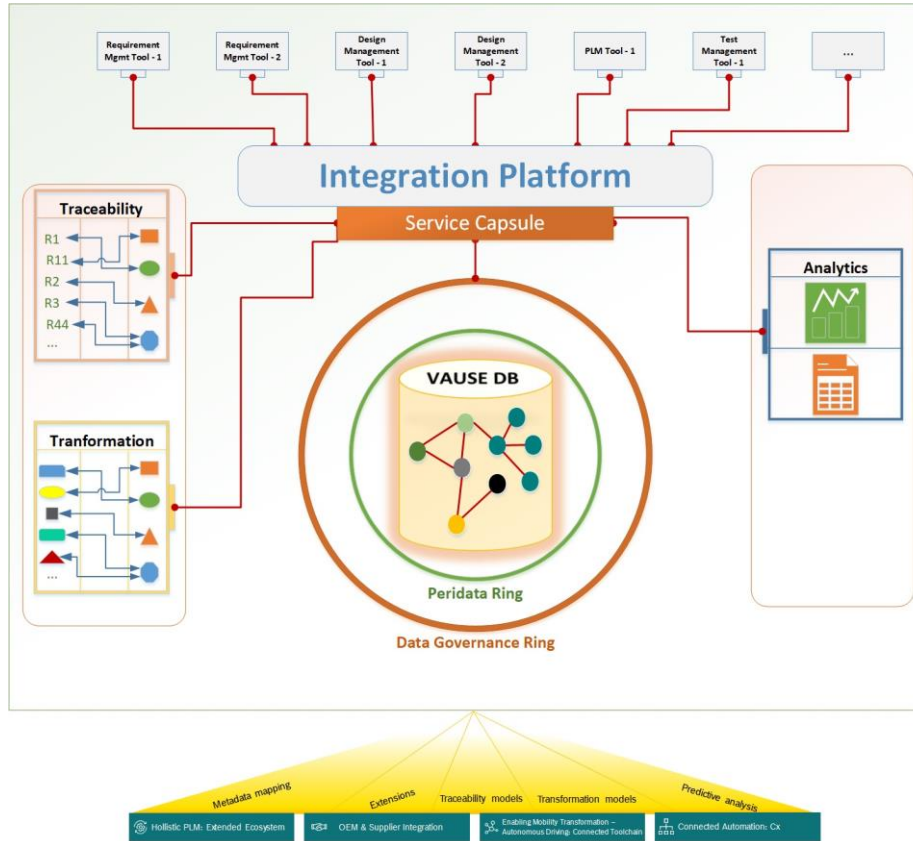
- While the customer is always looking for something new from a product, business sees a way to capture maximum market share of that product.
- Customer expects continued support from the product while the business wants to focus on evolution of its family of products.
- Customer never wants to move away from a brand unless the business has nothing more to offer that is trendy.

It is also on the business to see how to match this demand vs supply or be a trendsetter by thinking “first in business”. Technology is the underlying fact that helps enliven collaborated, continuous and integrated product development.

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<sup>10</sup> Servitization is a transformation journey - it involves firms (often manufacturing firms) developing the capabilities they need to provide services and solutions that supplement their traditional product offerings

<sup>11</sup> A circular economy is an economic system aimed at eliminating undesirable product cost by continual reuse of product features.



**Fig. 4.** Tool agnostic integration view

The above depiction shows that no matter what the category of tools are; whether they are requirements or testing of model management tools; they all can seamlessly integrate as long as the engineering can be centrally persisted. This also gives us an opportunity to apply AI/ML, ASPICE, cross-domain reference KPIs and transformations, etc.

Having understood so far, the bottom-line indication is continuous engineering. What we need for an efficient future is a concept that will allow software (ALM) and hardware (PLM) to seamlessly integrate, communicate and thus exchange product-engineering artifacts keeping product traceability in focus (to meet ISO/IEC 1550412 and ASPICE<sup>13</sup>).

<sup>12</sup> A standard for Information technology – Process assessment

<sup>13</sup> Automotive Software Performance Improvement and Capability dEtermination



This now becomes important to understand lifecycle integration & management concepts.

## 2.2 Relevance of lifecycle integration & management – key aspects

There are two aspects to lifecycle management

- Lifecycle Integrations – Landscapes having homogeneous & heterogeneous artifacts
- Lifecycle Management - Process standardization and Automations

### Homogeneous<sup>14</sup> Lifecycle Integration & Management.

When an organization has limited visibility of its need for lifecycle integration, it often goes for a short-term investment for a solution; a solution that specifically focuses on solving the requirement with constraints. Meaning, let us say your organization wants to solve a specific issue of defect exchange across engineering units, following the same discipline of lifecycle (either ALM or PLM). **Therefore, this terms to be a homogeneous lifecycle integration where similar lifecycle artifacts are involved.** This leads to simple, point-to-point lifecycle integration. This is termed as classic approach of the pre-millennium. A good representation of this scenario is seen below.

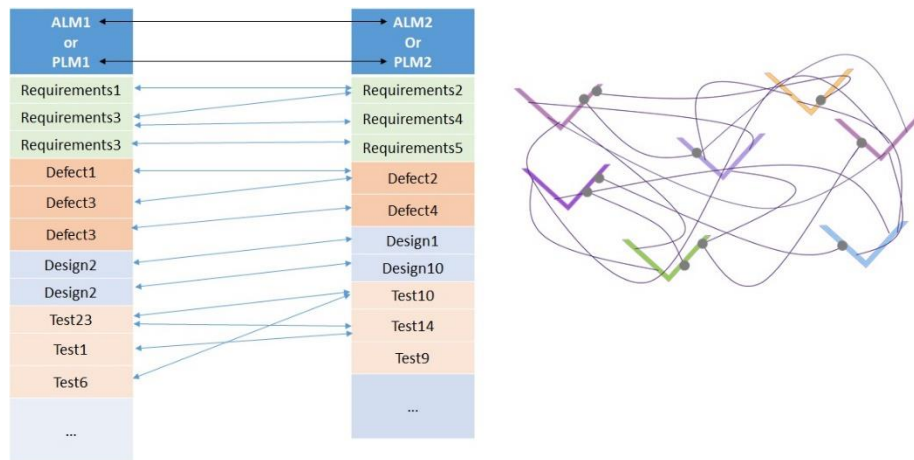


Fig. 5. Homogeneous lifecycle integration

### Achievement

- Simple and straightforward tool integration
- A limited lifecycle integration

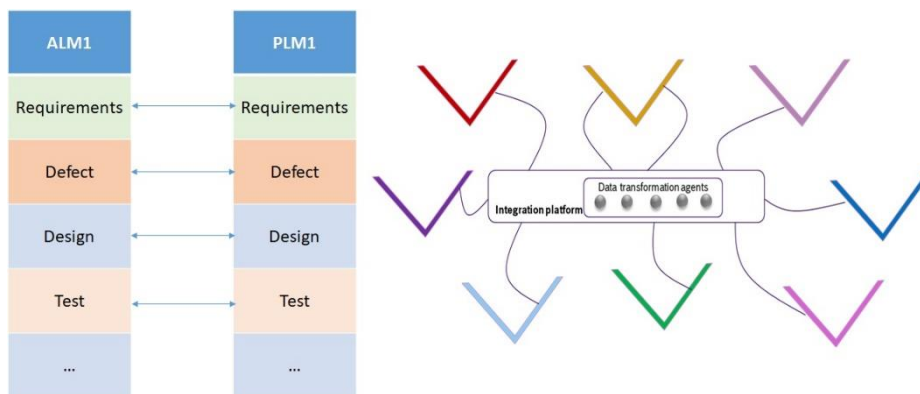
<sup>14</sup> All of same kind

### Continued challenges

- Frequent tool customization needed in order to maintain the integration through upgrades, etc.
- Cross lifecycle / tool integration is a challenge due to the incompatibility in the nature of data contained by the tool
- Changing a tool is a challenge, as it would break the integration mechanism
- Data non-transparency due to no cross tool integration (Ex: no integration possibility between requirements and design tools)
- Underlying technology of tools

### Heterogeneous<sup>15</sup> Lifecycle Integration & Management

When an organization aspires to achieve high degree of traceability and audit compliance, it often goes for a long-term investment for a solution; a solution that specifically focuses at integration of lifecycles at a product development level (ALM-PLM). Having said this, we can straightly assume the involvement of many engineering and non-engineering tools and technology to achieve such a high degree of compliance. This also means that the best way to achieve the compatibility is to use tools that are mutually compatible for lifecycle integration. Ex: requirements module in ALM has to ensure that it is compatible with requirements module in PLM. This means, the two disparate sets of tools following heterogeneous lifecycles are brought together via a mutually compatible interface. A good representation of this scenario is as seen below.



**Fig. 6.** Heterogeneous lifecycle integration

### Achievement

- Wider scope of lifecycle integration achieved with mutually compatible interface provided by a licensed vendor

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<sup>15</sup> Diverse in character and content

- Some amount of traceability achieved among compatible toolchains on either sides of the lifecycles

#### *Continued challenges*

- Organizations are still forced to adopt usage of compatible tools for the sake of lifecycle management
- The above constraint offers limited tool flexibility to engineering units
- Technology and tool upgrade continues to be difficult
- Maintenance and business aspects of closed loop lifecycle management or multi-modal engineering is still a far dream

Therefore, the bottom line issues and challenges of sustainable and continuous engineering, a trustworthy lifecycle management solution and achieving some of the critical business KPIs remain to exist. Organizations are now realizing that what we have until now is not sufficient to match the pulse of the market demands.

### **3 SLIM: RBEI's<sup>16</sup> Proposal for a Solution**

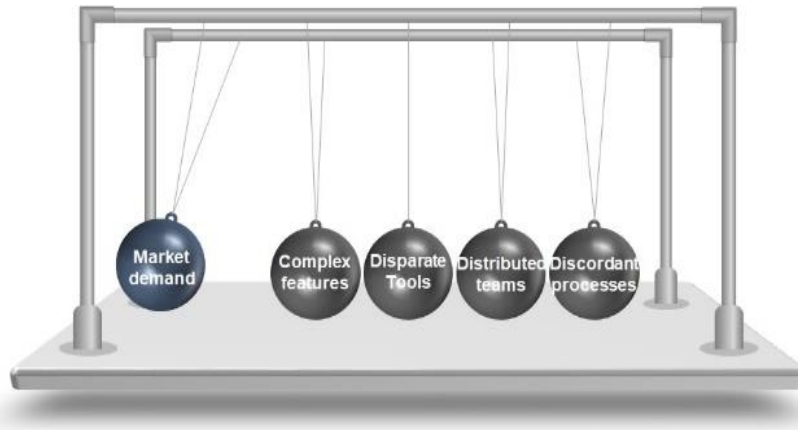
The key to building a Sustainable and Trustworthy multimodal<sup>17</sup> engineering establishment is to enable interoperability between disparate systems and processes involving varied standards and data formats. Product development organizations need and use these disparate tools and lifecycle processes resulting in a complex mesh of point-to-point connectivity that in turn becomes inefficient and unmanageable over a period. Technological compulsions and the varied cycle speeds of development make it cumbersome for an ecosystem of disparate tools and lifecycle processes to dovetail.

Product Development Organizations have traditionally struggled with islands of heterogeneous systems that use different standards and data formats leading to disjoint system or tightly coupled point-to-point integrations, which lead to high costs over a long run. Lack of efficient data exchange and lifecycle integration add to the lack of interoperability and maintenance. These problems lead to longer time to market, lack of traceability for product issues, unmanageable variability of products and increased costs. The need of the future is for a solution that enables engineering enterprises to collaborate efficiently using well-integrated heterogeneous engineering systems, coupled with lifecycle processes that enable easier development with business partners, and yet not introducing another tooling solution to burden already existing complicated engineering tooling landscapes.

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<sup>16</sup> Robert Bosch Engineering and Business Solutions Private Limited. <https://www.bosch-india-software.com/en/index.html>

<sup>17</sup> Application of multiple types of activities on the same medium



**Fig. 7.** Market demand and its influence on the systems

We do have many brands that offer lifecycle integration platforms to manage product and application lifecycle. What we have often experienced is that these available solutions work well only when our engineering systems integrate with them. This is the catch. Our engineering tooling landscape is so diverse with homegrown and proprietary tools that it simply becomes impractical to invest once again in another solution, just to get on to the chosen platform. In spite of doing so, we are still not certain if we can completely integrate with the platform in order to achieve **traceability** and **variability**.

Therefore, what we really need is a solution that will let us continue to use age-old tried-and-tested engineering tools and yet bind them together to exchange data and provide traceability and variability. Not stopping at this, we would also like if the same solution can extend to provide us an opportunity to apply AI/ML<sup>18</sup> & BI<sup>19</sup> to achieve predictability in our engineering.

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<sup>18</sup> Artificial Intelligence / Machine Learning

<sup>19</sup> Business Intelligence

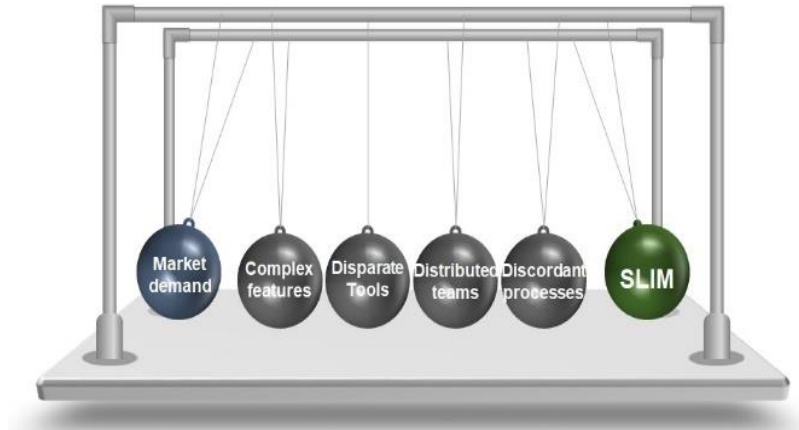


Fig. 8. SLIM to solve market demands

#### SLIM HIGHLIGHTS

- **Integrate any PLM to any ALM.**
- **Provide abstraction from multiple tools, data formats and standards.**
- **Support easier integration of new tools/systems by providing a configuration over programming approach – Integration Platform**
- **Model your business logic and data exchange rules into reusable templates**
- **Efficient transformation and traceability of heterogeneous engineering artifacts**
- **Provides multi-standard transformation compliance – VAUSE™**
- **Cross platform reporting and analytics – smart KPI dashboards**

**SLIM<sup>20</sup>** is a concept that opens up a wide range of solution possibilities with key building blocks that enable

- rapidly establishing interoperable engineering systems
- well connected lifecycle processes and secure data sharing ecosystem with OEMs, suppliers and engineering units
- predictable engineering

<sup>20</sup> Sleek Lifecycle Integration & Management

While SLIM enables you the above, it yet does not force another tool to an already existing complicated engineering tooling landscape. SLIM uses a combination of products like any integration platform and VAUSE™<sup>21</sup> to establish a feasible and elegant process that makes exchange mechanism between any PLM systems to any ALM system seamless. This relieves product development organizations that often find it arduous to establish such an integration, considering their complex and heterogeneous engineering practices. Below is a representation of such a concept where tools from any PLM system can communicate with tools from any ALM system.

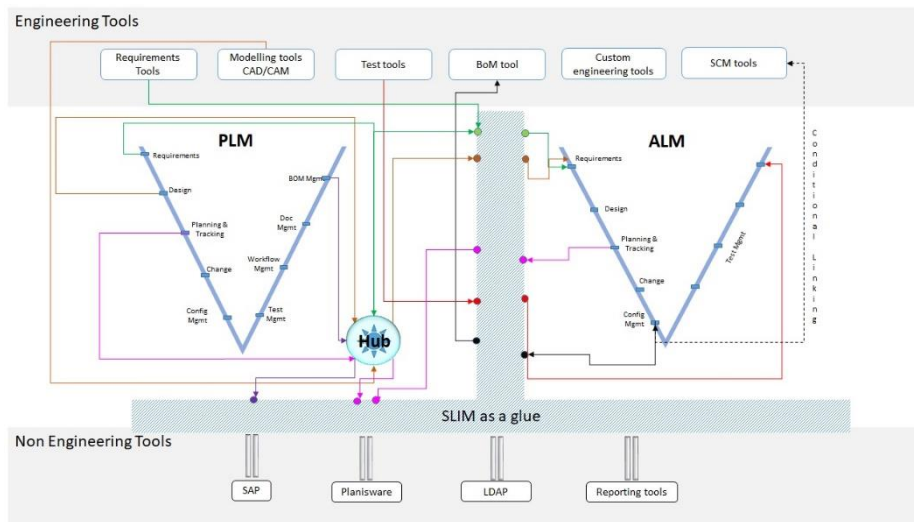


Fig. 9. Any ALM-PLM integration through SLIM as a glue

Having said this, the only next thought that comes to our minds is to **define a minimum basic exchange protocol that is tool agnostic**. Staying tool agnostic is the key differentiator. This is where SLIM uses integration platform products and VAUSE™ to achieve a tool agnostic lifecycle integration and management solution.

### SLIM – A Detailed View

<sup>21</sup> Vault of Archetypes for Unified Systems Engineering

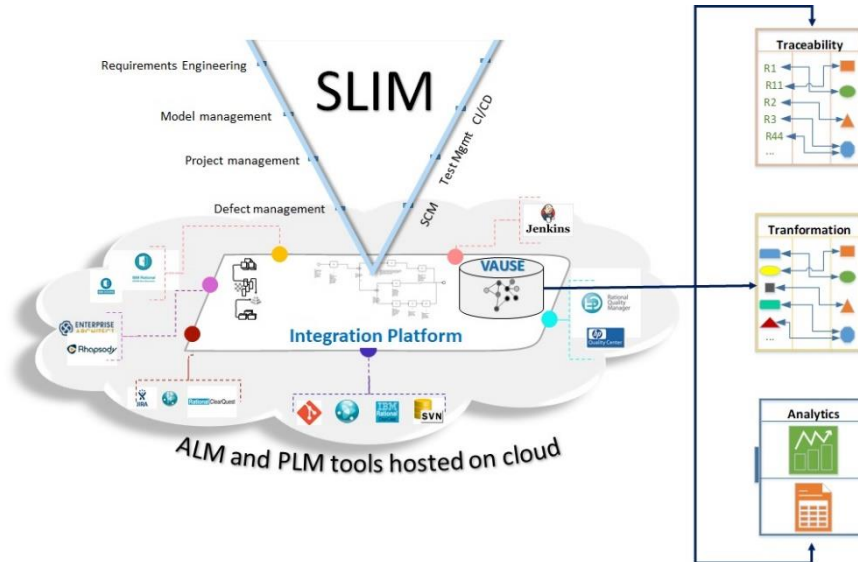


Fig. 10. Detailed view of SLIM

The above solutions serves multiple purposes such as:

- Lifecycle synchronization
- Migration
- SW exchange
- Partner integration
- Connected toolchain
- Connected automation to support blockchain<sup>22</sup> principles

#### BIP & VAUSE

**BIP is an in-house developed integration platform solution enabling an Any-to-Many integration solution that seamlessly orchestrates the interaction of heterogeneous engineering systems with transactional integrity. BIP –**

- **Provides integration platform to connect heterogeneous lifecycle tools**
- **Work Flow Modeler feature help construct lean protocols for integration**
- **Exposes extensions for transactional data reflection**

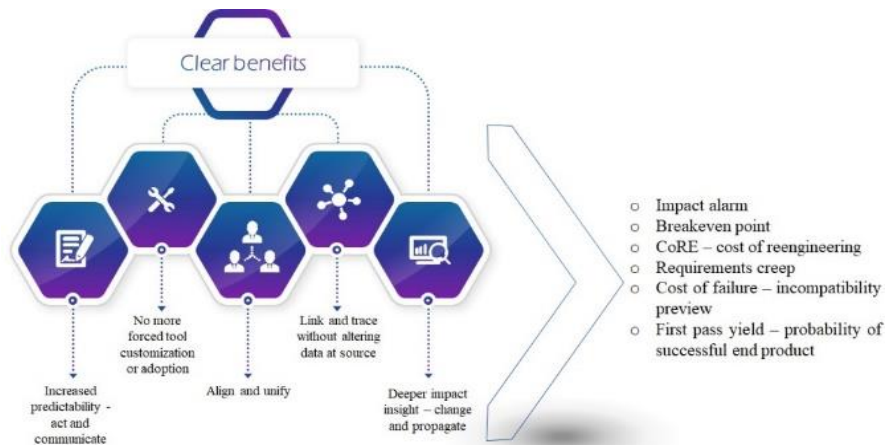
**Note: any integration platform solution enabling the basic minimum needs mentioned above could also be a good candidate for experimenting**

<sup>22</sup> Chain of growing block of data and records that are linked using cryptography

**VAUSE – is a vault of engineering artifacts references that makes SLIM tool agonistic integration solution. This solution provides the needed building blocks to**

- **Provide abstraction from multiple tools, data formats and standards.**
- **Support easier integration of new tools/systems by providing a configuration over programming approach**
- **Efficient transformation and traceability of data between different artifacts**
- **Meet multi-standard transformation compliance.**
- **Cater reporting and analytics**

Some of the benefits one may explore to realize:



**Fig. 11. Benefits of SLIM**

#### **4 Conclusion**

It is evident that organizations are in dire need of harmonizing product development to stay relevant in today's market. SLIM not only focusses on process automation and tools specific integration but also holistic product engineering enabling organizations to achieve this harmony by; involving software, hardware and product lifecycle as a whole, thereby giving an opportunity to bring any PLM to integrate with any ALM.

RBEI thus firmly believes that SLIM is the future of connected and continuous engineering that can help build an integrated ecosystem for a sustainable and trustworthy engineering.



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