Product Line Engineering Solutions for Systems and Software

Engineer your product line portfolio as a single production system rather than a multitude of products
For businesses to be competitive, today’s product development organizations must deliver a product line – a portfolio of similar products or systems with variations in features and functions – rather than just an individual product.

Systems and software product line engineering is an innovative approach that enables organizations to develop, deliver and evolve an entire product line portfolio, through each stage of the development lifecycle, with much higher degrees of efficiency than have been possible before.

What if the innovation, economy of scale, competitive advantage and profitability of your product line were limited only by your imagination, instead of the capacity of your engineering team?
The characteristic that distinguishes the systems and software product line engineering (PLE) approach from previous efforts is when an organization invests in a means of production that enables it to efficiently create a product line of similar systems from a consolidated set of soft assets such as requirements, designs, source code and test cases. Manufacturers of hard goods have long employed analogous engineering methods to create a product line of similar systems using a common factory that assembles and configures parts from a supply chain designed to be shared across the product line.

BigLever Software provides the industry’s leading PLE solution, offering your organization the infrastructure, tools, best practices and methods needed to create an advanced and efficient means of production for your product line. Companies that invest in a more efficient means of production for product line engineering and delivery can experience a discontinuous jump in productivity, quality, time to market and product line scalability.

The BigLever PLE solution opens new frontiers in innovation, economy of scale, competitive advantage and profitability, impacting the fundamentals of how you compete with your product line.

**Product lines and profitability**

In the world of hard goods, a product line refers to the variations on a common theme, where multiple similar products are combined into one line that offers different sizes, colors, features and functions, with a common goal of filling customer need for a particular kind of item. Economy of scale is a key aspect of the product line concept, where greater profitability is achieved by investing in an efficient means of production that can be used to deploy different “flavors” of a product.

As product differentiation and innovation expands from simple physical attributes to complex systems and software features – such as automotive cruise control that adapts to ambient traffic conditions, ships that can shoot down an errant satellite, wind turbines optimized for different environments and mobile phones that guide you back to where you parked your car – economy of scale and profitability become dependent on an efficient means of production for different “flavors” of products and the soft assets from which they are engineered, such as requirements, designs, source code and test cases.

In development organizations today, virtually all systems and software engineering is performed in the context of a product line. Nobody builds just one. Systems and soft-
ware product lines can be found in every industry across the spectrum, including aerospace, defense, automotive, medical, consumer electronics, computer systems, alternative energy, telecommunications, semiconductor fabrication, software applications, computer games, e-commerce and industrial automation systems. Systems and software product lines can be found in every business model, including retail products, government contractors, original equipment manufacturers (OEMs), business-to-business, value-added resellers and custom product development.

As businesses everywhere strive to gain competitive advantage and achieve greater profitability, the need for an efficient means of production for systems and software product lines has become universal.

**Product-centric thinking impedes portfolio production**

Throughout the first five decades of the systems and software engineering field, the methods and tools of the trade have predominantly promoted a product-centric perspective. The state of the industry today is a bevy of sophisticated product-centric development tools and processes that can be effectively applied to the development lifecycle of an individual product – from early inception through design, implementation, testing, deployment and maintenance.

However, these product-centric tools do not independently or collectively offer an effective means to engineer and deliver a product line. With product-centric tools, it is left as an exercise for tool users to craft the homegrown techniques for managing the “commonalities and variabilities” among products during the development of their product line portfolios.

The repercussions of taking a product-centric perspective in a product line setting are shown in Figure 2. The vertical gold bars highlight the product-centric focus on the development lifecycle of the individual products (A, B through N) in a product line. The red lines illustrate the complex, tangled and labor-intensive interactions, dependencies and coordination activities required to take advantage of what is common and to manage all the variations among the similar products as the product line portfolio evolves over time.

The crux of the problem in Figure 2 is that the number of red interdependency lines grows by the square of the number of products in the product line, explaining why complexity and effort increase exponentially faster than the growth of the product line. Making matters worse, the conventional product-centric traceability relationships between the different stages of the lifecycle for an individual product interact with the red product interdependency relationships, multiplying the complexity and introducing dissonance across the stages of the lifecycle.

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**Figure 2: Complex interdependencies resulting from the product-centric perspective**
These tactical development challenges are so large that they impede a company’s ability to achieve strategic business objectives, such as hitting marketplace windows, offering competitive pricing while maximizing profitability, meeting product quality demands, and expanding the scale and scope of the organization’s portfolio. Comparing the ad hoc, complex and labor-intensive nature of the product-centric perspective to the sophisticated means of production found in semiconductor fabrication or in automotive manufacturing makes clear that there is an extraordinary need and opportunity for dramatic improvements in systems and software product line engineering and delivery.

A shift in perspective to an efficient means of production

Organizations mired in the complexity, inefficiency and pain of product line engineering from a product-centric perspective experience a PLE epiphany when a shift in perspective reveals a simpler solution to the problem. Analogous to engineering a product line of hard goods, it is much more effective to view systems and software product line engineering as creating a means of production – a single system capable of automatically producing all of the products in a product line – rather than viewing it as creating a multitude of interrelated products. The powerful, though subtle, essence of the PLE epiphany is the focus on that singular means of production rather than a focus on the multitude of products.

Figure 3 shows the single production line perspective for producing the same product line as in Figure 2, where now the focus is on the means of production inside the red box. The same products, A through N (on the right side of the diagram), are automatically produced by a singular means of production composed of:

- Feature profiles (top) that describe optional and variable features for the products in the product line, where each product in the product line is uniquely defined by its own feature profile.
- Shared PLE assets (left) such as requirements, architectures, designs, models, source code components, test cases and documentation that can be configured and composed in different ways to create all instances of soft assets and products in a product line. Variation points shown within these PLE assets support feature-based variation management.
- Product configurator (center) that automatically composes and configures products from the shared PLE assets, using the feature profiles to determine which shared assets to use and how to configure variation points within the assets.

“We can’t solve problems by using the same thinking we used to create them.”

—Albert Einstein
As highlighted by the gold bars in Figures 2 and 3, tilting your head 90 degrees provides the critical shift in perspective, from the vertical product-centric focus of Figure 2 to the horizontal PLE production line focus in Figure 3.

By shifting perspective to focus on the singular means of production rather than the multitude of products, the products are relegated from the primary focus to a consequential corollary of the automated means of production. The exponential complexity of manually managing product interdependencies is eliminated and replaced by automated production, resulting in dramatic increases in the number of products that can be effectively created, deployed and maintained.

With the PLE production line perspective, the scale of a product line and the scope of diversity within the product line can be based on business opportunities and profitability rather than the complexity limitations imposed by the product-centric perspective.

The BigLever Gears PLE Lifecycle Framework and PLE Methodology

BigLever Software’s proven and pragmatic PLE solution, BigLever Software Gears™, enables you to take the single production line perspective and create an automated, optimally efficient means of production for your systems and software product lines. With BigLever’s industry-standard Gears PLE Lifecycle Framework™ and 3-Tiered PLE Methodology™, you have all the essential elements you need, out of the box, to make a discontinuous jump in capability from product-centric approaches into the new frontier of PLE innovation, efficiency and profitability.

BigLever provides the software infrastructure, tools, integrations, methodology, best practices and expertise to guide you through a systematic and incremental transition to an operational Gears production line, precisely as illustrated in Figure 3. By focusing both your business and engineering teams on the operation of your production line, your organization can plan, develop, deploy and evolve your product line portfolio, seamlessly and efficiently,
across every stage of your development and delivery life-
cycle – from business case and analysis, to requirements,
design, implementation, testing, delivery, maintenance and
evolution.

The award-winning Gears PLE Lifecycle Framework
provides a set of industry-standard PLE concepts and
constructs that augment your tools, assets and processes
across the entire lifecycle:

• A feature model that you use to express the feature
diversity (optional and varying feature choices) among
the products in your product line.

• A uniform variation point mechanism that is available
directly within your tools and their associated assets,
to manage feature-based variations in all stages of the
engineering lifecycle.

• A product configurator you use to automatically assem-
ble and configure your assets and their variation points
– based on the feature selections you make in the fea-
ture model – producing all of the assets for each product
in your product line with the push of a single button.

A key capability of the Gears PLE Lifecycle Framework
is the integration of PLE concepts into your tools, assets
and processes across the systems and software devel-
opment lifecycle. Gears is compatible off-the-shelf
with many of the industry standards in programming
languages and compilers, integrated development
environments, requirements management, change and
configuration management, build systems, quality man-
agement, model driven development, word processors
and documentation. Figure 4 illustrates how the different
PLE concepts and constructs expand your collection of
tools and processes – making them product line aware –
in three dimensions of distinct and synchronous PLE
concerns:

• Multi-product. The feature-based variation manage-
ment and automated production line necessary to
engineer and deliver the multiple products in a product
line are provided directly by the Gears feature model,
variation point mechanism and product configurator.

• Multi-phase. The tools necessary to support the mul-
tiple phases of a product line engineering lifecycle are
the same tools you use today, augmented by the Gears
PLE Lifecycle Framework to provide consistent variation
management and PLE operations. Traceability mechanisms that are traditionally used for managing the interdependencies among the assets across multiple phases of the engineering lifecycle are also extended to become product line aware, where traceability relationships and consistency analysis becomes aware of the implications of a variation point at either or both ends of a traceability relationship.

- Multi-baseline. Change management and configuration management for a product line are done on multiple evolving baselines of the PLE assets rather than on a multitude of individual product baselines. Analogous to the supply chains for automotive manufacturing being aligned on baselines for different model years, the supply chain of soft assets for systems and software product lines are aligned on baselines at different points in time, to synchronize complete and consistent sets of assets for the delivery of products in a product line.

The final piece of the BigLever Gears solution is the 3-Tiered PLE Methodology, shown in Figure 5. This pragmatic new-generation PLE methodology enables a practical tiered approach that allows you to remove barriers, make a non-disruptive transition and successfully operate your Gears production line. Each tier builds upon and is enabled by the previous tier:

- Base tier (1): Feature-Based Variation Management and Automated Production: Tools, integrations and infrastructure for engineering product line features, product feature profiles, product line hierarchy, feature-based variation points in assets, and automated feature-based configuration of product line assets into products and deliverables.
- Middle tier (2): Feature-Based Asset Engineering: Processes and organizational structures for engineering the full lifecycle of product line assets – from requirements to architecture, design, implementation and test – on multiple delivery streams in a production line.
- Top tier (3): Feature-Based Portfolio Management: Business-wide management of a product line portfolio by the features offered and the profile of features allocated to each product.
Industry-leading successes, experience and expertise
With over a decade of experience, successes and industry leadership, BigLever’s technology, methodology and expertise have played an instrumental role in establishing many of the industry’s most acclaimed PLE practices. BigLever customers, including four Software Product Line Hall of Fame inductees, have received significant industry recognition for their innovation and breakthrough success in implementing PLE approaches.

The BigLever PLE solution now offers you out-of-the-box capabilities to initiate and operate your own systems and software production line, and to begin reaping the dramatic benefits in the new PLE frontier.

Benefits of systems and software product line engineering and delivery with BigLever Software Gears
With the BigLever PLE solution, your business and engineering organization can shift perspective to focus on a singular production line capable of automatically producing the products in your product line from a supply chain of PLE assets, rather than focusing on the manual creation of a multitude of products. With this shift in perspective, the complexity of managing multiple products with their exponential interdependencies is eliminated and replaced by the automated means of production.

Similar to what is seen when adopting an efficient manufacturing system, the resulting benefits give rise to a discontinuous jump in capability, not measured in percentage points but more often measured in multiples or order-of-magnitude strategic improvements such as:

- An increase in the scope of product diversity and the scale of different products that can be effectively delivered in a product line.
- An increase in productivity and efficiency, a reduction in per-product development cost and overhead, and higher profit margins.
- A reduction in time to market for new and updated products, and an increased agility to assertively react to new opportunities and changing marketplace conditions.
- An increase in product quality, a reduction in defect density and improved risk management.

The exciting thing about discontinuous jumps in capability is that they open up new frontiers in innovation, competitive advantage and profitability, offering new possibilities that were not easily conceivable in the past. By using PLE to more quickly deliver larger numbers of precisely targeted products, with better quality and with less effort than your competitors, you can successfully capture marketplace leadership.

A pivotal strategic benefit of the BigLever PLE solution is the shift away from product-centric product marketing to feature-based portfolio marketing. The diversity of products that can be automatically produced by a BigLever production line is a direct consequence of the scope of the feature variations designed into the production line. Thus, the traditional role of product marketing – defining the individual products to take to market – is elevated to product line portfolio marketing. With feature-based portfolio marketing, the scale and scope of the portfolio are defined in terms of the common features and feature diversity supported by a Gears production line and the feature profiles that describe each of the products delivered to market.

Some of the dramatic strategic benefits that come from the new paradigm of feature-based portfolio marketing include:

- Portfolio features become the lingua franca among product marketing professionals, business executives, engineering managers and even the automated Gears production line, which can significantly improve communication and alignment among stakeholders.
• Adding a new product to the portfolio can now be a simple matter of creating a new feature profile to drive the automated Gears production line.

• Adding, updating or extending the portfolio with a new feature or feature combination is now a simple matter of delta engineering – extending the Gears production line to support the new feature, either as a common feature for all products or as a varying feature option available in a subset of the products.

• Because of the low cost and effort required to extend the product line portfolio, new products become commodities rather than resource-intensive investments. Even small, niche, one-off or low-margin opportunities can be profitable to pursue.

Using the BigLever PLE solution, you can define the scale and scope of your product line portfolio based on business opportunities and revenue optimization. You no longer have to be constrained by the complexity and limitations of product-centric approaches.

Stepping into the new PLE frontier

The BigLever PLE solution opens new frontiers for innovation and profitability in systems and software product line engineering and delivery, as illustrated in Figure 6. The fundamental PLE shift in perspective allows you to focus the business and engineering teams for your product line on creating an efficient means of production – a Gears production line – rather than creating a multitude of products.

The BigLever PLE solution provides advanced, proven and pragmatic PLE capabilities. The BigLever Gears PLE Lifecycle Framework offers a consistent and integrated product line engineering solution for the tools and assets that span the systems and software development life-cycle. The incremental 3-Tiered PLE Methodology offers non-disruptive and seamless transitions from current practices into a more efficient and effective PLE practice. Our expert services can help you apply the new generation of proven, practical and successful PLE practices to the specific needs of your organization.

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For more information
To learn more about the BigLever Gears Product Line Engineering Tool and Lifecycle Framework, contact:

info@biglever.com
www.biglever.com
+1-512-777-9552


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BigLever Software Gears is protected by U.S. Patent Nos. 7,543,269, 8,156,470, and 8,918,754. Patents Pending.

BigLever Software, Inc.
10500 Laurel Hill Cove
Austin, TX 78730
U.S.A.

“Give me a lever big enough and I will move the world.”
—Archimedes