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Product Line Acquisition in the DoD: The Promise, The Challenges

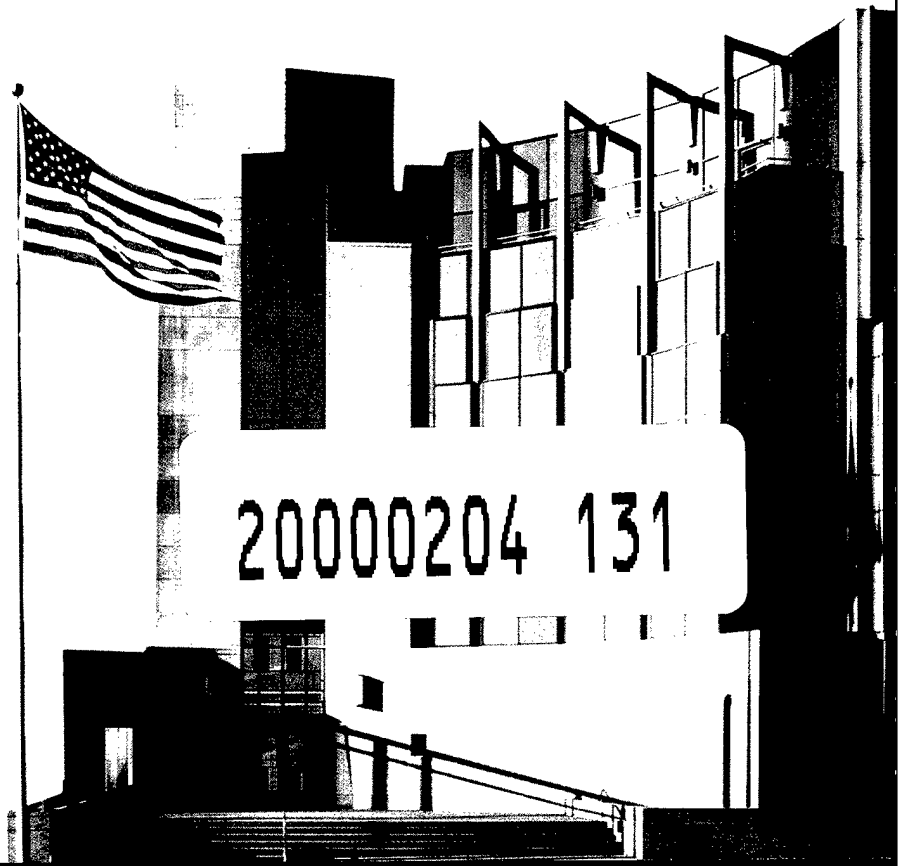
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Product Line Practice Initiative

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Abstract

Industrial use of software product line technology has resulted in some impressive savings, while also improving product quality and delivery time. Although there has been some successful use of this technology within the Department of Defense (DoD), there are special challenges. This paper presents the basics of product line practices and reports the results of two DoD product line workshops in which important issues and successful practices were shared.

1 Introduction

Do you find yourself continually acquiring software-intensive systems that are similar to ones you have paid for in the past? Do you wish you could use your scarce resources to buy what is truly *new* functionality without also having to pay for re-development of essentially the same old solutions? Some solutions to these frustrations are found in a maturing technology that is ripe for exploitation: software product line practice. Through this technology, a growing number of commercial organizations are reporting impressive reductions in costs, faster delivery of mission capability, and improved quality. To help transition this promising technology to the DoD, the Software Engineering Institute (SEI) established the Product Line Systems Program.

While this technology has great promise and relevance for DoD needs, key issues must be addressed to take advantage of this successful commercial practice. In this paper we will provide some insight into this important technology and its application within the DoD. After providing some background, including key concepts and relevance to the DoD, we will present some practical results from two SEI DoD Product Line Workshops. By sharing the experience of successful DoD product line practice, we hope to allow others to take advantage of this promising technology.

2 Background

This section will provide some necessary background information. First, we will define some key terms. Next, we will provide some documented evidence of the benefits of a product line approach. We then discuss how a product line approach supports DoD policy. Finally, we point to the challenges and opportunities to the DoD that will be more fully elaborated in Section 3.

2.1 Key Concepts

The field of product lines is new enough to offer different definitions for similar concepts. The SEI has settled on a definition that brings together the key intent of these sometimes-competing definitions. We define a product line to be a group of products sharing a common, managed set of features that satisfy specific needs of a selected market or mission. For example, a telecommunications company may offer a number of cellular phones that share a similar market strategy and an application domain, thus making up a product line. The products in a software product line can best be leveraged when they share a common architecture that is used to structure components from which the products are built.

The architecture and components are central to the set of core assets (sometimes referred to as the *platform*) used to construct and evolve the products in the product line. In other words, a software product line can best be leveraged by managing it as a product family, which is a set of related systems built from a common set of assets. For example, if the product line of cellular phones is built from a common architecture and set of common components, it is managed as a product family. When we refer to a product line, we always mean a software product line built as a product family. This particular use of terminology is not nearly as important to us as the underlying concepts involved, namely, the use of a common asset base in the production of a set of related products.

Product line practice is therefore the systematic use of software assets to modify, assemble, instantiate, or generate the multiple products that constitute a product line. Product line practice involves strategic, large-grained reuse as a business enabler.

Since software reuse is not a new concept, what is different about this from earlier, less successful reuse efforts? A key difference is that early efforts focused on small-grained reuse of code. The cost of creation and use of these small-grained assets often outweighed the modest gains. Over the years, reuse technology has evolved to focus on progressively larger-grained assets. Today, the state of the art is to reuse strategic, large-grained assets unified by a software architecture. Using this approach, reuse can result in remarkable efficiency and

productivity improvements and time economies [Brownsword 96, Bergey 98]. In combination with the known benefits of process improvement and technology innovation, systematic reuse through a product line approach offers great promise to software development and acquisition organizations.

2.2 Benefits of a Product Line Approach

A number of organizations have already gained order-of-magnitude improvements in efficiency, productivity, and quality through a product line approach. Often even more important than cost savings is the fact that product line practice enables an organization to get its product to field more rapidly. As Robert Harrison, Naval Systems Warfare Center, succinctly stated, "The right answer delivered late is the wrong answer" [Bergey 98].

A few examples of the reported benefits follow. The Swedish naval defense contractor, CelsiusTech, reported a reversal in the hardware-to-software cost ratio, 35:65 to 60:20, that now favors the software [Brownsword 96]. Hewlett-Packard has collected substantial metrics showing two to seven times cycle time improvements with product lines. Motorola has shown a four times cycle time improvement with 80% reuse. Cummins engines realized a decreased time for system build and integration from about one year to three days. Among other commercial domains that have shown equally dramatic results are air traffic control (Thompson), commercial bank systems (Alltel), telecommunication systems (Ericsson, Nokia, Lucent, AT&T), and college registration systems (Buzzeo).

The reported benefits are compelling, but what do you actually *do* when you engage in a product line approach? In the next section we describe the high-level, essential product line activities.

2.3 The Essential Activities of a Product Line Approach

At its essence, fielding a product line involves *core asset development or acquisition*, and *product development or acquisition* using those core assets [Clements 99]. These two activities can occur in either order, or (most commonly) in concert with each other. Core asset development/acquisition has been traditionally referred to as domain engineering. Product development/acquisition from core assets is often called application engineering. The entire process is staffed, orchestrated, tracked, and coordinated by management. Figure 1 illustrates this triad of essential activities. The iteration symbol at the center represents the decision processes that coordinate the activities.

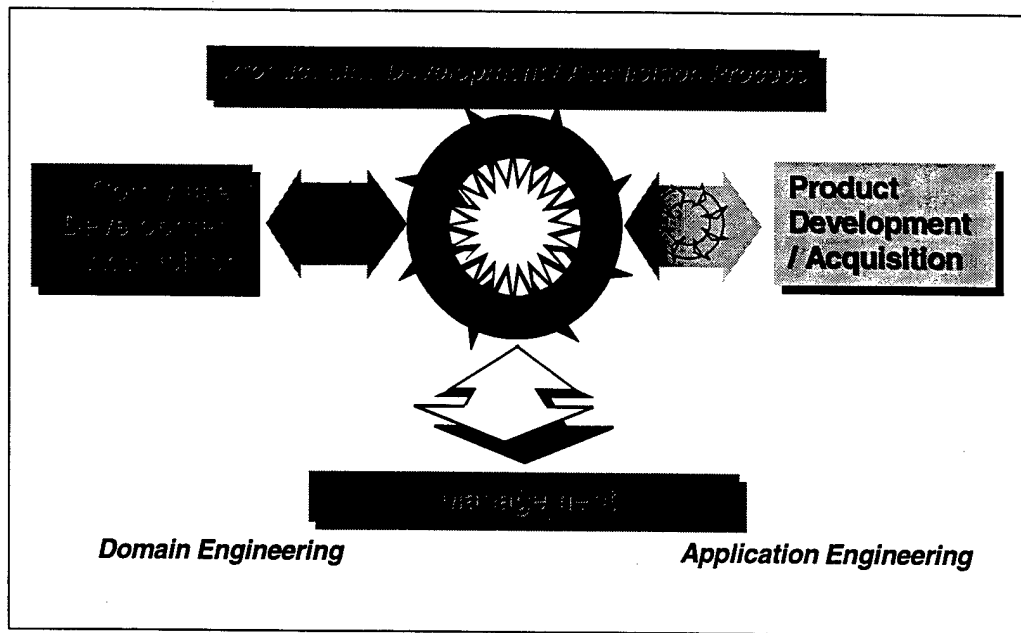


Figure 1: Essential Activities of Product Lines

The bi-directional arrows indicate not only that core assets are used to develop products, but that revisions or even new core assets might, and most often do, evolve out of product development. The diagram does not specify which part of the diagram is entered first. In some contexts, already-existing products are mined for generic assets that are then migrated into a product line. At other times, the core assets may be developed or procured first in order to produce a set of products that is merely envisioned and does not yet exist.

There is a strong feedback loop between the *core assets* and *products*. Core assets are refreshed as new products are developed. In addition, the value of the core assets is realized through the products that are developed from them. As a result, the core assets are made more generic by considering potential new products on the horizon. Finally, both the core asset and the product development or acquisition are themselves iterative, as illustrated in Figure 1.

While it is evident that product line practice calls for a new technical approach, new non-technical and business practices are equally crucial. There is a constant need for strong visionary management to invest the resources in the development or acquisition of the core assets and to develop the cultural change to view new products in the context of the core assets. As we will see, the non-technical challenges may be the most significant for the DoD.

2.4 Relevance and Challenges to the DoD

Some might ask what these largely commercial practices have to do with the DoD. First of all, there is no doubt that commonality of DoD requirements is abundant. For example, many DoD organizations have developed their own payroll systems, budgeting systems, and command and control systems that are essentially duplicates of others. In response to this commonality of requirements, there is a growing recognition within the DoD that new acquisition approaches leveraging best commercial practices must be implemented [Bergey 98]. At the top DoD policy levels, acquisition reform from DoD Directive 5000.1 and DoD Regulation 5000.2-R have focused on using these best practices to reduce cost, schedule, and technical risks, and to advanced architecture-based approaches to reuse that support open systems, interoperability, and commercial off-the-shelf (COTS) components. Former and current top-level policy makers have expressed how important it is that the DoD use innovative, commercially proven practices to reduce cycle time, improve quality, reduce cost, improve efficiency, and reduce technical risks. These facts establish a clear linkage between DoD needs, policy and product line practice [Bergey 99].

While we know that product line practice works in industry, many attempts to emulate this success within DoD have encountered problems. In fact, there are those who believe that there are inherent structural impediments against product line practice within DoD. While the technical challenges are not to be underestimated, even if they are solved, significant non-technical barriers must be addressed [Foreman 96]. In the DoD, many of these non-technical issues translate into acquisition-related issues. Yet there is hope. There have been several reuse efforts within the DoD, and there are certainly examples where the systematic reuse and horizontal leverage characteristic of a product line approach have occurred and are occurring [Bergey 98].

Why have some attempts succeeded where several have failed? The successful organizations have found ways to identify and address some of the key acquisition-related issues. In the next section we will present the results of two hands-on DoD workshops in which many issues and some answers were identified. Because this is a relatively new endeavor, many questions are unresolved. However, there have been enough successes to provide some optimism for the future.

3 Some Issues and Strategies for the DoD - Product Line Workshop Results

The SEI DoD Product Line Practice workshops were held in March 1998 [Bergey 98] and March 1999.¹ Their purpose was to identify industry-wide best practices in software product lines, to share DoD product line experience, to explore the technical and non-technical issues involved, and to discuss ways in which the current gap between commercial best practice and DoD practice can be bridged. In each workshop, more than 30 workshop participants represented joint agencies, all services, non-DoD agencies, and industry. All participants had experience with product lines or other strategic reuse approaches.

The participants formed working groups to consider the general areas of software engineering, technical management, and organization management for both acquisition organizations and contractors. After identifying the specific practices to discuss, the general approach of each working group was to

- describe the practices in a DoD context
- identify barriers for implementing the practices within the DoD
- identify strategies to overcome those barriers

Following the same structure, we present highlights of the results most directly related to a DoD acquisition organization considering adopting a product line approach. Results from both workshops are summarized here. The practices covered are

- building and communicating a business case
- developing and implementing a product line Concept of Operations
- providing an appropriate funding model
- achieving the right organizational structure
- developing and implementing an acquisition strategy
- contractor interface

¹ Bergey, John; et al. *Second DoD Product Line Practice Workshop Report* (CMU/SEI-99-TR-015). Pittsburgh, PA: Software Engineering Institute, Carnegie Mellon University. Expected publication: November 1999.

Please note that this list is not purported to be an exhaustive list of all the issues. However, these are critical issues that the participants were able to address in the context of the workshop.

3.1 Building and Communicating a Business Case

Given sound business goals as a basis for evaluation, a business case will play a strategic role in deciding whether a product line approach makes sense for a DoD organization. The current environment of downsizing and escalating demands for "better, faster, cheaper" system development may make building a business case more straightforward. While data from outside organizations may be useful to initiate concept exploration, hard evidence obtained from pilots within the organization is essential.

Participants identified the following prerequisites for building the business case:

- selectivity about where and when to apply a product line approach (multiple mission areas may need different approaches)
- solid justification including anticipated savings or pay-back for candidate systems
- incentives for achieving efficiency

Some of the significant barriers to implementing this practice in the DoD relate to organizational structure and funding models. These will be discussed later in this section.

One mitigation strategy is to include a rough draft of the product line Concept of Operations with the business case to provide insight into how the product line concept will work within the organization. This will help to substantiate the considerations are, in fact, valid for the organization.

3.2 Developing and Implementing a Product Line Concept of Operations

Once a business case has been established to support a product line approach, it is important to begin creation of a product line Concept of Operations (CONOPS)² to define how the implementation will be accomplished. The CONOPS will be best developed in an iterative fashion. As noted in the previous section, a draft CONOPS can be an important vehicle to identify key issues that must be resolved, such as which organizations will participate, how

² The CONOPS applies to the development/acquisition and evolution of the product line and should not be confused with the traditional DoD concept of operations that describes the operational system.

the approach will be funded, and processes and structures for initiating and sustaining the approach. As these issues are resolved, the CONOPS can be refined.

A fully developed CONOPS identifies product line stakeholders and clearly describes their roles and responsibilities. Typical contents include appropriate mechanisms for sustaining the product line over its life cycle, improvement feedback mechanisms, customer interface, and other support functions essential for long-term success. The CONOPS should address the operation of both the acquisition organization and development groups as well as the role of the product line architecture.

Workshop participants stressed that the key pitfall in creating a CONOPS was to adopt a “Big Bang” strategy that was too grandiose. Such a strategy ignores the reality that a product line approach should evolve incrementally, preferably from grassroots support that builds upon initial successes within the organization. Since the CONOPS describes how a product line approach will work in a particular environment, the document itself can serve as a practical way to identify a wide range of barriers and how the organization will mitigate them.

The SEI has developed guidance for CONOPS creation based on experience with several government organizations [Cohen 99]. This may be found on the SEI Web site (<http://www.sei.cmu.edu>).

3.3 Achieving the Right Organizational Structure

A key part of a product line CONOPS is a description of the organizational structures involved. The workshop participants agreed that achieving the right organizational structure is one of the greatest challenges in implementing a product line approach. Implementing a product line approach is dependent on managing horizontally (i.e., in a matrix mode) across projects to produce products that are part of a family built around a common architecture and core set of assets, as well as managing vertically to create individual products. This presents a real challenge for DoD organizations that are traditionally highly “stovepiped” with regard to their sponsorship, project structure, funding, resources, contracting, and reward system. As one participant stated, “we [in the DoD] are horizontally challenged.”

A primary consideration in a product line approach is structuring the organizational units responsible for developing/acquiring and sustaining the core assets versus those responsible for developing/acquiring derivative products using the core assets. These organizational considerations raise many questions about control and funding of the architecture and other core assets, how the core assets will be responsive to project-specific requirements, and support for acquisition of assets and products.

The wrong organizational structure can defeat solid product line technology and processes. Moreover, achieving the right organizational structure involves both determining the appropriate structure and an effective strategy to implement it. It is also the case that the

definition of the right organizational structure may change as the product line matures. The challenge in creating such a suitable organizational structure is to avoid making wholesale changes that can be unduly disruptive to the culture of the work place, while at the same time trying to align the organization with product line goals that cut across project efforts. The working group again returned to the theme of starting small as a key risk mitigation means. Choose a well-scoped product line with modestly scoped organizational change rather than attempt a risky enterprise overhaul.

3.4 Providing an Appropriate Funding Model

The funding model is closely linked to the CONOPS, organizational structure, and the business case. This model identifies funding sources to initiate and support the product line approach. Developing a suitable funding model involves clearly laying out a product line approach over multiple systems and identifying the life-cycle cost savings and benefits to senior level management to obtain their buy in.

One of the participants stated that "seed money" is essential to overcoming objections, and without it there may be no practical way to get started and demonstrate savings. Although there was general agreement that the product line startup risk should ideally be addressed through research and development (R&D), the current funding structure often works against this.

Suggestions for creating a funding model include the following:

- obtaining grassroots support to convince sponsors and projects of the benefit of the product line solution rather than management directing a solution
- reallocating a portion of the funds from programs that will benefit from the product line approach and using those moneys to fund the product line
- aligning funding to support the long-term plan and justifying seed money from other areas (including using R&D funds for pilot projects)
- creating a horizontal funding line as a firm part of the budget based on product line feasibility and return on investment

A major barrier that was cited is that the organizational unit responsible for developing the Concept of Operations is not usually in charge of the funding model. This reemphasizes the need for a product line funding mechanism that can align sponsorship with horizontal areas that cut across projects. Other barriers that were discussed include funding instability, parochial views of organizations opposed to the pooling of funds, restrictions on the use of funds (e.g., color of the money), and a lack of incentives for an enterprise approach to systems development that transcends organizational units and commands.

3.5 Developing and Implementing an Acquisition Strategy

All of the participants indicated that developing and implementing a suitable acquisition strategy is critical to achieving a product line approach in DoD. One of the key perceived differences in implementing a product line approach in the DoD environment, as opposed to commercial ventures, is the predominant role that acquisition plays. The acquisition strategy defines how to deal with product lines within the contracting environment of the DoD and still be responsive to unique project requirements. One participant suggested that the DoD contracting environment provides a lot of freedom; a big challenge is to find the appropriate contractual vehicle and recognize that the early "buy-in" and endorsement of the contracting officer and contract negotiator play a very pivotal role in the acquisition strategy.

A key issue for the DoD participants in developing a product line acquisition strategy was how to competitively acquire derivative products without endangering contractor interests or the government's ability to maintain control over the core assets. Another concern is the issue of liability for any government-provided components.

A common concern of the group is that proven acquisition approaches (i.e., ones that are repeatable and responsive to life-cycle requirements) constitute a major unknown, and will need to be gradually developed, refined, validated in actual practice, and disseminated. Guidance is especially needed on how to include architecture issues in a Request for Proposals (RFP).

The participants of the Second DoD Workshop identified several different specific acquisition strategies. Generally, these strategies differed in the degree to which the government owned the product line assets. In increasing ownership of assets these strategies were

- to acquire a product built using product line technology (no government ownership of assets)
- to acquire a reference architecture to serve as a basis for future acquisitions of specific system architectures, assets, and products
- to acquire a system architecture and a set of components from which future systems may be built. The US Army Common Hardware/Software (CHS) system is a successful example of this strategy.
- to acquire a system architecture, a set of components, and at least one product built using these assets. The US Army Crusader howitzer program is a successful example of this.

Generally, as you work up the scale of increasing government ownership of assets, the risks associated with having unvalidated assets decreases. However, the risks associated with the scope of the acquisition, the expense, and the commitment required increases.

Other areas where it was indicated that acquisition guidance is needed to support a product line approach include

- developing an acquisition plan and selecting a suitable contract vehicle(s) that is compatible with the product line concept and takes full advantage of Acquisition Reform measures
- preparing solicitation packages and specifying appropriate technical evaluation criteria
- including precautionary measures to minimize the risk of a protest before or after contract award
- incorporating contract incentives to sustain contractor motivation (after contract award), and to encourage cooperation and efficiency commensurate with their role as a product line team player

All of these measures are aimed at overcoming the traditional mindset of a single-system acquisition program and accommodating multiple project efforts.

3.6 Contractor Interface

Members of the group observed that at the organizational level, the interface to the contractor and the contractor product line practices seemed to be tightly coupled to the acquisition approach of the DoD project. At least for traditional, single-system acquisitions, the business and funding models; the organizational structure and operations; the resource development and allocation processes; and other senior management practices seemed to be based on the customary acquisition practices of the DoD.

Comparing the traditional enterprise to the product line enterprise, a few issues come to the forefront.

The first issue concerns the contractor's business model. Contractors now have multiple and different business opportunities. They can focus their business on one or more of three roles

1. lead contractor for architecture
2. subsystem/asset developer
3. systems developer/integrator

The presence of choices raises important questions, such as

- What are the criteria that would lead a contractor to choose one business opportunity over another?
- Would not most contractors opt to lead architecture development for the contract security and competitive advantage it provides over asset developers and system integrators?

The second issue concerns shared commitment. For a product line approach to be successful, the working group believed that contractors and the acquisition organization must share responsibility and commitment to cost avoidance through systematic reuse. How is this achieved?

The third issue concerns contractor buy-in of a product line architecture. Systems integrators will not be motivated to use a mandated product line architecture that may not reflect their design practices. System development risks and costs may be greater, particularly if the contractor has no experience and assurance that the architecture is valid. The architecture will be "dead on arrival." How is this scenario avoided?

Having all interested contractors collaborate on developing a product line architecture may resolve the above issues, but this may not be feasible in all cases. For example, the architecture may be an open systems standard, or only one contractor may have the needed expertise. In addition, are there cases when the performance and schedule risk of an architecture by consensus is too great?

There are no clear-cut answers to these issues, but a joint government-industry approach to these issues must be developed for long-term product line success.

4 Summary and Conclusions

There are many benefits to a product line approach and many organizations have succeeded in realizing these benefits. Yet there are also costs and risks for any product line program. Nevertheless, if properly managed, the benefits of a product line approach far exceed the costs. Strategic software reuse through a well-managed product line approach holds great promise for the DoD in terms of efficiency, time to field mission capability, and quality.

The SEI vision for product lines is that this practice will pervade software engineering in the new millennium, and we are committed to helping the DoD succeed in the successful exploitation of this technology. To assist in this exploitation, the SEI Product Line Systems Program has established the Business Acquisition Guidelines project. This project exists to address product line acquisition challenges within the DoD. We invite you to visit our Web site to learn more about our work in this important area:
(http://www.sei.cmu.edu/plp/bus_acq_guide.html).

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Appendix A: A Product Line Practice Framework

The SEI is capturing the essential elements of product line practice in an evolving framework, *A Framework for Software Product Line Practice*. Organizations that have succeeded with product lines vary widely in the nature of their products, their market or mission, their organizational structure, their culture and policies, their software process maturity, and the extensiveness of their domain expertise and legacy artifacts. Nonetheless, there are universal essential elements and practices that are emerging. The framework focuses on these universals while accommodating various organizational contexts and starting points.

There are essential practices in a number of specific areas that are required to produce the core assets and products in a product line and to manage the process at multiple levels. The framework describes the essential practice areas for software engineering, technical management, and organizational management, where these categories represent disciplines rather than job titles. For individual practice areas, the framework highlights the delta for the product line approach versus an approach for single-system development.

The Framework is a living document that is being developed incrementally and validated and updated based on feedback from practitioners. To view the most recent version of the Framework, please visit the SEI web site at <http://www.sei.cmu.edu>.

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Contact Information and Feedback

SEI Technical Notes on Business and Acquisition Guidelines for Product Lines

Comments or suggestions about this first in a series of technical notes on *software product line business and acquisition guidelines* are welcome. We want this series to be responsive to the needs of DoD and government personnel involved in the business and acquisition aspects of implementing software product lines. To that end, comments about this technical note, inclusion of other topics, or any other issues or concerns will be of great value in continuing this series. Comments or suggestions should be sent to

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