
Exploring Acquisition Strategies for Adopting a Software Product Line

John K. Bergey and Lawrence G. Jones
Software Engineering Institute, Carnegie Mellon University

Abstract:

Many organizations are attracted to the well-documented benefits of a software product line approach. However, special challenges surround product line acquisition in the Department of Defense. We explain some basics of software product line practice, the challenges that make product line acquisition unique, and three basic acquisition strategies. We next describe the key contractual tasks a supplier must perform and map these to an enterprise view of product line acquisition. Using this context, we explain roles and responsibilities for the organizations involved, and describe important activities and deliverables. This provides a basis for building the necessary artifacts for a successful acquisition.

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* without having to pay for re-development of essentially the same old solutions? If so, you should consider a software product line approach.

A *software product line* is a set of software-intensive systems sharing a common, managed set of features that satisfy the specific needs of a particular market segment or mission and that are developed from a common set of core assets in a prescribed way [Clements 2002]. An increasing number of organizations are building their products as product lines in order to achieve large-scale productivity gains, improve time to field or market, maintain a market presence, compensate for an inability to hire, leverage existing resources, and achieve mass customization.

Commercial implementations of software product lines have resulted in some impressive results [Clements 2002, Schmid 2002]. Although there has been some successful use of this technology within the Department of Defense (DoD), it carries special challenges for both the acquisition office and the supporting development contractors.

This paper addresses software product lines from the perspective of an acquisition organization. Product line acquisition involves adopting some new practices and rethinking some old practices. To introduce you to this new way of thinking we first provide a brief overview of software product line practice. We then describe the acquisition challenges implied by this technology, the basic acquisition strategies you can pursue, and the foundational contractual tasks that must be specified for successful product line acquisition. Against this background we then explore the structures, roles, and activities that will emerge during the lifetime of the product line from an enterprise perspective. We conclude by pointing to areas of future work to facilitate adoption of a product line acquisition approach.

2. Software Product Line Basics

An operating software product line organization embodies a core asset development activity and a product development activity, all orchestrated by a management activity. Figure 1 illustrates this triad of essential activities.



Figure 1: The Three Essential Product Line Activities

The arrows indicate not only that core assets are used to develop products, but also that revisions or even new core assets can evolve out of product development. The diagram does not specify where the process starts. In some contexts, existing products are mined for generic assets that are then migrated into a product line. At other times, the core assets may be developed first to produce an envisioned set of products. Core assets include plans, requirements, designs, documentation, and tests, as well as software.

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 of the core assets and to nurture the cultural change to view new products in the context of the product line, rather than as stand-alone systems.

In January 1997, the Carnegie Mellon[®] Software Engineering Institute (SEI) launched the Product Line Practice Initiative to help facilitate and accelerate the transition to sound software engineering practices using a product line approach. The goal of this initiative is to provide organizations with an integrated business and technical approach to systematic reuse, so they can produce and maintain similar systems of predictable quality more efficiently and at a lower cost.

[®] Carnegie Mellon is registered in the U.S. Patent and Trademark Office by Carnegie Mellon University.

A key strategy for achieving this goal has been the creation of the SEI *Framework for Software Product Line Practice*SM (“the framework”). The framework describes the foundational product line concepts and identifies the essential activities and practices that an organization must master before it can successfully field a product line of software or software-intensive systems. The framework is a living document that is evolving as experience with product line practice grows. Version 4.0 is described in the book *Software Product Lines: Practices and Patterns* [Clements 2002], and the latest version is available on the SEI Web site [Northrop 2009].

3. Software Product Line Acquisition Challenges

Bergey and Fisher define acquisition as “*The process of obtaining products and services through contracting. Contracting includes purchasing, buying, commissioning, licensing, leasing, and procuring of designated supplies and services via a formal written agreement*” [Bergey 1999]. Contracting works best when tasks are precisely defined. Moreover, contracting is best suited to efforts that are

- based on past experience, including use of familiar practices and processes
- based on well understood cost history data
- well bounded—that is, involving a fixed set of tasks and traditional deliverables in a well defined context (known requirements, quantity, schedule, and funding)
- unlikely to involve significant changes or redirection downstream

In the real world you won’t have these ideal conditions, so typically there are challenges to any type of acquisition. What can make a product line acquisition especially challenging is when the acquisition must meet the needs of *multiple programs and target systems* that transcend *multiple platforms and developers*. DoD acquisition policies and infrastructure don’t help since they are still largely predicated on acquiring one-of-a-kind, stove-piped systems. Other factors that make product line acquisitions more challenging are

- Planning a family of software products that rely on a common development effort is not a traditional DoD acquisition paradigm.
- There is no institutionalized means for funding the development and sustainment of a product line across multiple programs.
- Typically, neither program offices nor contractors are incentivized to adopt a product line approach.
- Adopting a product line approach may force the government to assume system integration responsibility.

Despite these challenges, many DoD organizations have successfully implemented software product lines. Several DoD and Army product line workshops have confirmed that programmatic issues—not technical issues—are the main impediments to widespread adoption of product line practices in the DoD [Bergey 2003, Bergey 2004, Bergey 2005, Bergey 2006, Bergey 2009].

The essence of *product line acquisition* is obtaining a software product line through contracting. The first step, addressed in the next section, is to address the contracting challenges by selecting an appropriate acquisition strategy.

SM Framework for Software Product Line Practice is a service mark of Carnegie Mellon University.

4. Basic Acquisition Strategies for Acquiring Software Products via a Product Line

Developing a suitable acquisition strategy is a key consideration in adopting a product line approach in the DoD. A program manager (PM) can choose from three basic strategies:

Acquisition Strategy 1: *A PM commissions a contractor to develop products using the contractor's proprietary software product line.* This strategy involves acquiring products directly from a contractor that has an existing product line. An example is the Textron Overwatch Intelligence Center (OIC) product line [Jensen 2009].

Acquisition Strategy 2: *A PM commissions a government organization to develop a software product line.* This strategy involves acquiring a government-owned product line (production capability and products) using the in-house capabilities¹ of a designated government acquisition organization. An example is the Army's Advanced Multiplex Test System (AMTS) [Cohen 2007].

Acquisition Strategy 3: *A PM commissions a contractor to develop a government-owned software product line.* This strategy involves acquiring a government-owned product line (production capability and products) from a contractor. An example is the Live Training Transformation / Common Training Instrumentation Architecture (LT2/CTIA) product line of the Army's PEO STRI [Bergey 2009].

The difficulty in executing these different strategies varies significantly since they require different levels of management sophistication and technical skills on the part of the acquisition organization. Related considerations include the data rights to product line artifacts, and the risk of a supplier going out of business. Of the three approaches presented, the most challenging is Acquisition Strategy 3; the outcome is more unpredictable, thus making the risk to the government greater.

Some of the most successful product line efforts reported to date in government acquisitions were based on Strategy 1 [Brownsword 1996, Jensen 2007] and Strategy 2 [Cohen 2002, 2007]. Strategy 3 offers potentially huge rewards but is the most challenging to execute. However, several success stories have been reported [Bergey 2009, 2010].

5. Contractual Tasks for a Software Product Line Acquisition

At a high level, a software product line acquisition (

¹ This may include using the services of local Systems Engineering and Technical Assistance (SETA) contractors.

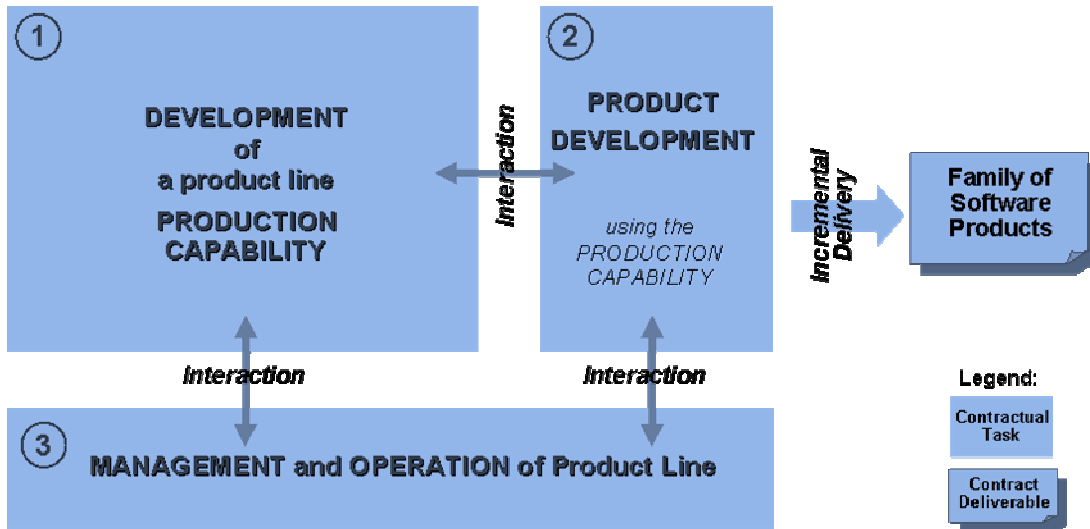


Figure 2) consists of three contractual tasks that a developer must perform. These tasks are

1. the development of a product line production capability
2. the development of a family of software products using that production capability
3. the management and operation of the product line

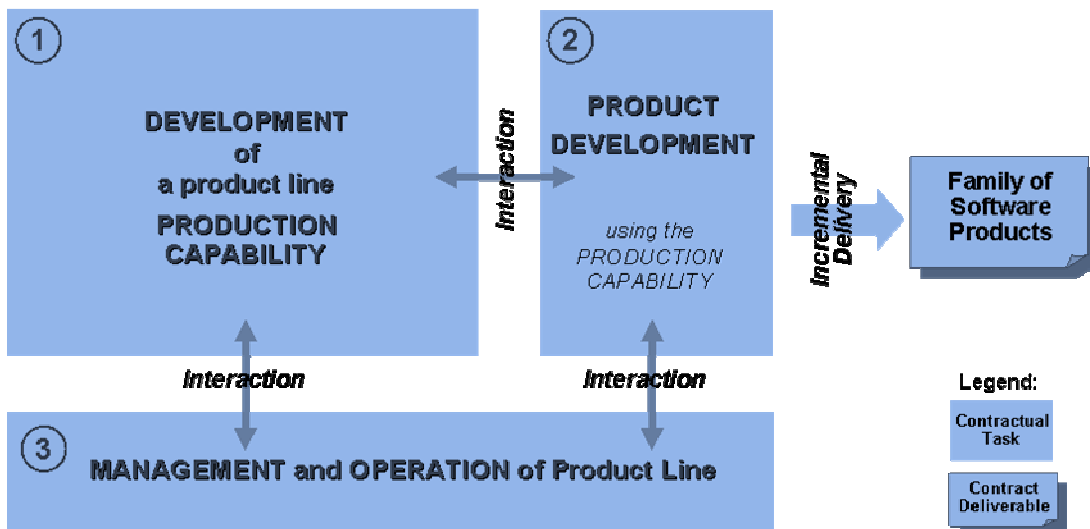


Figure 2: Three Major Contractual Tasks for a Software Product Line Acquisition

A *product line production capability* includes the product line core assets, a production plan to specify how to build products from the core assets [Chastek 2002], and the infrastructure to support the production operation. A *software development plan*, a traditional contractual deliverable, can be used to describe and govern the development of the product line production capability. Product developers then use the production capability to develop specific products within the product line. A *product line adoption plan* describes the approach for initiating the product line, and a *product line concept of operations* describes the approach for managing and operating the product line.

To operationalize these tasks we must assign specific responsibilities to specific organizational units. To help do this, it is useful to consider an enterprise view of the acquisition, described in the next section.

6. An Enterprise View for Software Product Line Acquisition

An enterprise view helps to frame the various aspects of a product line initiative. Such a view can help clarify important questions such as:

- How will the effort be organized?
- What will be the roles and responsibilities of the different organizational units?
- What deliverables will be produced? And what groups will be responsible for them?
- How will product line practices, such as *product line requirements engineering*, be implemented from an enterprise perspective?

Figure 3 shows an example of an enterprise view that corresponds to Acquisition Strategy 3 (described in Section 4). This example captures the essence of the major product line activities in an acquisition context and helps ensure that all stakeholders have a common understanding of the ramifications of the approach.

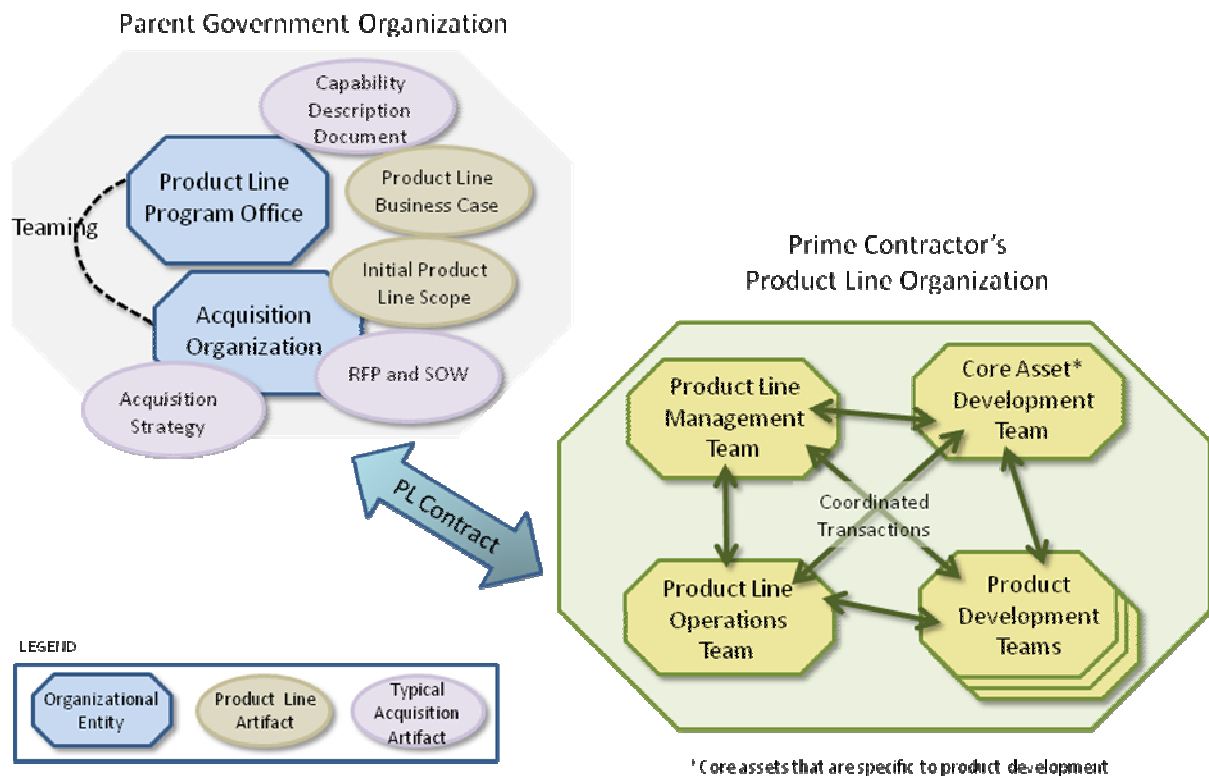


Figure 3: Sample Enterprise View of a Product Line Acquisition

The two primary organizational elements are the *parent government organization*, which is responsible for acquiring the product line, and the *prime contractor's organization*, which is responsible for implementing and sustaining the product line.

The subdivision of the prime contractor's product line organization into a *management team*, a *core asset team*, a *product development team*, and an *operations team* is just one example of how a developer organization might implement a product line approach. In this configuration, the *management team*, *core asset team*, and *operations team* are the organizational elements that are responsible for establishing the production capability that the *product development teams* will use.

The view in Figure 3 may be expanded to depict details of product development (Figure 4). This view shows how a *product development team* would interface with the other teams and use the *product line production capability* to develop products. Each product is an example of strategic reuse of the product line's core assets. This view identifies the contract deliverables that a product development team would produce. Since acquisition organizations have a penchant for thinking in terms of contractual deliverables, this view facilitates an understanding of how a product line functions and of the roles and responsibilities of the various teams.

Accordingly, this example shows that the product development team is initially responsible for producing a product specification. Following this, the team must develop any unique software components that are not part of the core assets and create a production plan for building the specific product that will satisfy the product specification. Another key deliverable is a product test plan that would draw on the existing testing artifacts that are also part of the core assets. Of course, this assumes the product team will be responsible for the initial testing of the product as well as generating any other related artifacts, such as test cases for unique software components and attached processes describing how to use them.

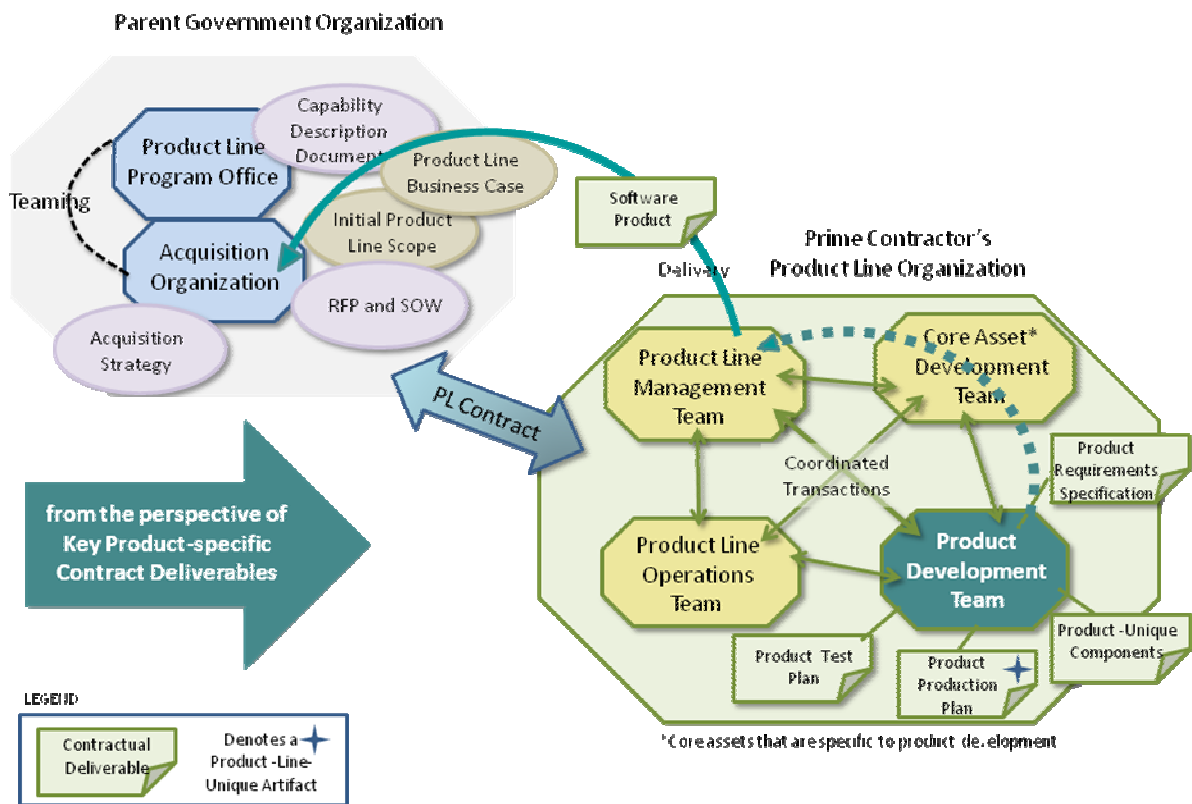


Figure 4: A View of a Product Development Team Using the Product Line Production Capability

Apart from the product itself, the major deliverable item is the *production plan*. It includes the process to be used for building a product from the core assets and lays out the project details to enable execution and management of the process (e.g., by including such details as the schedule, bill of materials, and metrics).

The importance of carefully specifying all deliverables cannot be overstated. The government needs to be proactive in specifying the required deliverables in the RFP/contract or the acquisition will be problematic.

7. A Customer View of Software Product Line Acquisition

Figure 5 depicts a product line acquisition from a customer perspective and shows the customer's interaction with the product line operations. While there are several potential customer views, this one depicts the simplest case where the program office is also the customer. The program office is the customer when the product being developed is for a system under the jurisdiction of the program office.

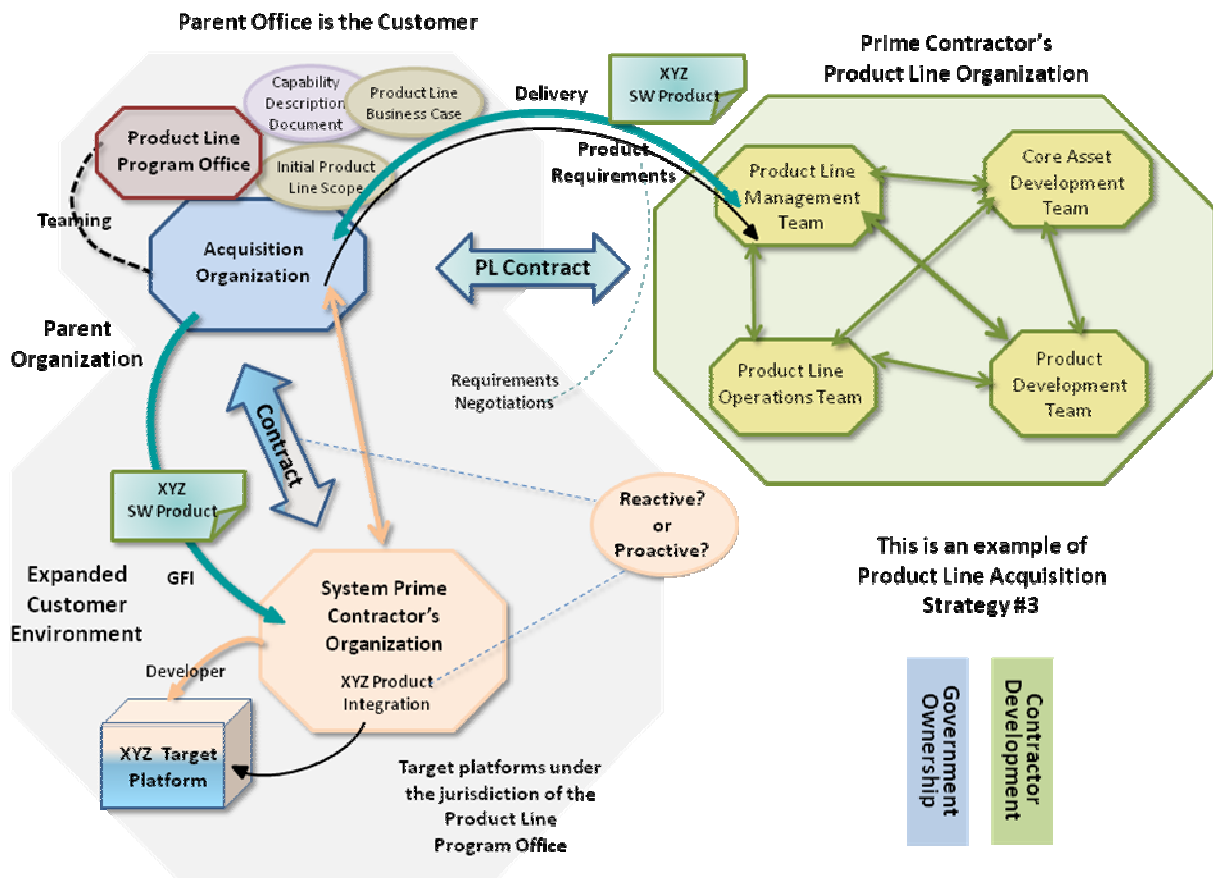


Figure 5: Simplest Case of Customer Interaction with Product Line Developer

While the program office is ultimately responsible for the product and its targeted system, a system prime contractor (under contract to the program office) is the agent that is actually responsible for developing and sustaining the target system. This situation corresponds to the relationship depicted in Figure 5 between the *parent organization* and the *expanded customer environment*. In this context, the

arrows shown in Figure 5 depict a scenario that leads to delivering a new product (in the product line family) to the customer. The corresponding sequence of events in this scenario is described below:

1. The program office analyzes and specifies the new product requirements (in conjunction with its acquisition organization and the contractor responsible for the target system).
2. The program office tasks the product line contractor with developing a new product (in accordance with the negotiated product requirements).
3. The product line contractor develops the new product and delivers it to the program office.
4. The program office (in conjunction with its acquisition organization), in turn, supplies the product as a government furnished item (GFI) to the target system contractor.
5. The target system contractor appropriately integrates the product into the target system.
6. The program office or its acquisition organization appropriately brokers any problems that arise in deploying the product with the product line contractor and the target system contractor.

An interesting aspect is that if the product line developer were a government organization (e.g., an Army Software Engineering Center (SEC)) instead of a system prime contractor, it would give the program office more flexibility, since Federal Acquisition Regulation (FAR) considerations wouldn't come into play. Contractors would still play a significant role, however, because SEC's typically contract with many suppliers to acquire needed skills, expertise, and resources. Such a situation would correspond to Acquisition Strategy 2. Even though this arrangement simplifies things, the enterprise view is still useful for clarifying the concepts.

The ideas here can be extended to the more complicated situation, where the customer is not the program office that is responsible for the product line, but is rather a different program office that has jurisdiction over other target systems. Exploring that type of engagement can be important because it represents the vision of many product line advocates.

8. Future Considerations

Among future activities the SEI is pursuing to promote product line acquisitions and make them more effective and commonplace in the DoD are

- providing *sample acquisition strategies* (e.g., involving a competitive down select) that an acquisition organization can use via appropriate tailoring
- creating *a comprehensive work breakdown structure (WBS)* for use as a management tool to govern a product line initiative
- creating *an acquisition timeline* with deliverables and specifying a series of *contractual events for technically monitoring and evaluating a product line effort*
- creating *sample SOW contract language* for acquiring a software product line
- creating a *sample contract data requirements list (CDRL)* and *data item descriptions (DIDs)* for key software product line deliverables

9. Conclusion

Developing a suitable acquisition strategy is a key element for any DoD program that is considering adopting a product line approach. Moreover, a proactive acquisition approach greatly enhances the

likelihood that a DoD product line initiative will succeed. In a reactive approach, an acquisition organization may not have an effective contractual means for managing the product line and performing its technical oversight and contract monitoring responsibilities.

If a program office is going to commission a contractor or government organization to develop a product line, the acquisition organization needs to specify the SOW tasks carefully to ensure product line aspects are appropriately covered and key deliverables are included. Creating a product line-specific WBS and a product line concept of operations from the acquirer's perspective are a good starting point.

An enterprise view provides an apt basis for describing a product line initiative from an acquisition perspective. This enables stakeholders to have greater insight and understanding of what a product line acquisition actually entails; it is useful for

- determining the division of responsibilities between the program office, acquisition organization, and development organization
- understanding stakeholder interactions and interdependencies and assigning specific roles and responsibilities
- understanding the “contracting realities” of different candidate approaches that are typically glossed over and become problematic downstream unless they are addressed up front
- stimulating discussion, analyzing different “acquisition threads,” and answering pertinent questions such as
 - How is the product line effort being organized and managed?
 - How do requirements flow from the customer to the core asset team?
 - How does an external developer use the core assets to develop a product?
 - What is the information flow for sustaining products that are in the field?

Experience has shown that if a program office is interested in adopting a product line approach, a good starting point is to conduct an acquisition-planning workshop with stakeholders early in the program-planning phase.

References/Bibliography

Bergey, J. Fisher, M.; & Jones, L. (1999). *The DoD Acquisition Environment and Software Product Lines* (CMU/SEI-99-TN-004). Pittsburgh, PA: Software Engineering Institute, Carnegie Mellon University, 1999. <http://www.sei.cmu.edu/library/abstracts/reports/99tn004.cfm>

Bergey, J. et al. (2003). *Fifth DoD Product Line Practice Workshop Report* (CMU/SEI-2003-TR-007). Pittsburgh, PA: Software Engineering Institute, Carnegie Mellon University. <http://www.sei.cmu.edu/publications/documents/03.reports/03tr007.html>

Bergey, J.; Cohen, S.; Jones, L.; & Smith, D. (2004). *Software Product Lines: Experiences from the Sixth DoD Software Product Line Workshop* (CMU/SEI-2004-TN-011). Pittsburgh, PA: Software Engineering Institute, Carnegie Mellon University. <http://www.sei.cmu.edu/publications/documents/04.reports/04tn011.html>

Bergey, J.; Cohen, S.; Donohoe, P.; & Jones, L. (2005). *Software Product Lines: Experiences from the Seventh DoD Software Product Line Workshop* (CMU/SEI-2005-TR-001). Pittsburgh, PA: Software Engineering Institute, Carnegie Mellon University. <http://www.sei.cmu.edu/publications/documents/05.reports/05tr001.html>

Bergey, John & Cohen, Sholom. (2006). *Product Line Acquisition in a DoD Organization—Guidance for Decision Makers* (CMU/SEI-2006-TN-020). Pittsburgh, PA: Software Engineering Institute, Carnegie Mellon University. <http://www.sei.cmu.edu/publications/documents/06.reports/06tn020.html>

Bergey, J.; Cohen, S.; Donohoe, P.; Fisher M.; Jones, L.; & Little, R. (2009). *Software Product Lines: Report of the 2009 U.S. Army Software Product Line Workshop* (CMU/SEI-2009-TR-012). Pittsburgh, PA: Software Engineering Institute, Carnegie Mellon University.

Bergey, J.; Cohen, S.; Donohoe, P; & Jones, L. (2010). *Software Product Lines: Report of the 2010 U.S. Army Software Product Line Workshop* (forthcoming). Pittsburgh, PA: Software Engineering Institute, Carnegie Mellon University.

Brownsword, L. & Clements, P. (1996). *A Case Study in Successful Product Line Development* (CMU/SEI-96-TR-016). Pittsburgh, PA: Software Engineering Institute, Carnegie Mellon University, 1996. <http://www.sei.cmu.edu/pub/documents/96.reports/pdf/tr016.96.pdf>

Chastek, G. & McGregor, J. (2006). *Guidelines for Developing a Software Product Line Production Plan* (CMU/SEI-2002-TR-006). Pittsburgh, PA: Software Engineering Institute, Carnegie Mellon University, 2002. <http://www.sei.cmu.edu/publications/documents/02.reports/02tr006.html>

Clements, P. (2002). Clements, P.; Northrop, L. *Software Product Lines: Practices and Patterns*, Addison-Wesley, 2002.

Cohen, S.; Dunn, E.; & Soule, A. (2002). *Successful Product Line Development and Sustainment: A DoD Case Study* (CMU/SEI-2002-TN-018). Pittsburgh, PA: Software Engineering Institute, Carnegie

Mellon University. <http://www.sei.cmu.edu/publications/documents/02.reports/02tn018.html>

Cohen, S. & Capolongo, K. "A Product Line Architecture for Army Aviation Diagnostics and Maintenance: Views and Evolution." *SATURN 2007 Conference*. Pittsburgh, PA, May 2007.
<http://www.sei.cmu.edu/library/assets/SATURNCohenPL.pdf>

Jensen, Paul. (2007). "Experiences with Product Line Development of Multi-Discipline Analysis Software at Overwatch Textron Systems,"35–43. *SPLC 2007: Proceedings of the 11th International Software Product Line Conference*. Kyoto, Japan, September, 2007. Los Alamitos, CA: Institute of Electrical and Electronics Engineers, Inc.

Jensen, Paul. (2009). "Experiences with Software Product Line Development." *CrossTalk* 22, 1 (January 2009): 11–14.
<http://www.dtic.mil/cgi-bin/GetTRDoc?AD=ADA499051&Location=U2&doc=GetTRDoc.pdf>

Northrop, L. Clements, P. et al. (2009). *A Framework for Software Product Line Practice Version 5.0*.
<http://www.sei.cmu.edu/productlines/tools/framework/index.cfm>, 2009.

Schmid, K. Verlage, M. (2002). "The Economic Impact of Product Line Adoption and Evolution," *IEEE Software*, Jul/Aug 2002, pp 50-57.

Author Biographical Information

John Bergey joined the SEI in 1993 as a visiting scientist and became a member of the technical staff in 1995. Currently, John is a member of the Research, Technology, and Systems Solutions Program (RTSS) and is active in the Architecture Centric Engineering and Product Line Practice initiatives. His role in these initiatives is to proactively assist DoD programs in applying SEI technologies (e.g., product line practices, the ATAM, and the QAW) to improve their acquisition practices and reduce software acquisition risk. Before coming to the SEI, John was a software division manager with the U.S. Naval Air Development Center.

Lawrence G. Jones is a Senior Member of the Technical Staff in the Product Line Systems Program at the Software Engineering Institute (SEI) of Carnegie Mellon University. Prior to joining the SEI, he served a career in the US Air Force and is the former Chair of the Computer Science Department at the Air Force Academy. His PhD in computer science is from Vanderbilt University. He's a senior member of the IEEE and ACM, a Fellow of ABET and the CSAB, and a member of the ABET Board of Directors.

Exploring Acquisition Strategies for Adopting a Software Product Line

Originally presented at the 7th Annual Naval Postgraduate School Acquisition Research Symposium
May 11-13, 2010
Monterrey, California

Author Contact Information

John K Bergey
Software Engineering Institute
Carnegie Mellon University
55 Woodard Court
Doylestown, PA 18901

Office: 215 348-0530
Home: 215 348-4991
Cell: 267 337-2944
Fax: 215 348-5255
email: jkb@sei.cmu.edu

Lawrence G. Jones
Software Engineering Institute
Carnegie Mellon University
1155 Kelly Johnson Blvd., Suite 111
Colorado Springs, CO 80920

Office: 719 548 4744
Home: 719 488 0255
Cell: 719 661 8566
Fax: 719 548 4750
email: lgj@sei.cmu.edu