



EXCERPT FROM THE PROCEEDINGS

OF THE SEVENTH ANNUAL ACQUISITION RESEARCH SYMPOSIUM WEDNESDAY SESSIONS VOLUME I

**Acquisition Research
Creating Synergy for Informed Change
May 12 - 13, 2010**

Published: 30 April 2010

Approved for public release, distribution unlimited.

Prepared for: Naval Postgraduate School, Monterey, California 93943



Report Documentation Page			Form Approved OMB No. 0704-0188		
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1. REPORT DATE MAY 2010		2. REPORT TYPE		3. DATES COVERED 00-00-2010 to 00-00-2010	
4. TITLE AND SUBTITLE Exploring Acquisition Strategies for Adopting a Software Product Line				5a. CONTRACT NUMBER	
				5b. GRANT NUMBER	
				5c. PROGRAM ELEMENT NUMBER	
6. AUTHOR(S)				5d. PROJECT NUMBER	
				5e. TASK NUMBER	
				5f. WORK UNIT NUMBER	
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) Carnegie Mellon University, Software Engineering Institute, 1155 Kelly Johnson Blvd., Suite 111, Colorado Springs, CO, 80920				8. PERFORMING ORGANIZATION REPORT NUMBER	
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)				10. SPONSOR/MONITOR'S ACRONYM(S)	
				11. SPONSOR/MONITOR'S REPORT NUMBER(S)	
12. DISTRIBUTION/AVAILABILITY STATEMENT Approved for public release; distribution unlimited					
13. SUPPLEMENTARY NOTES 7th Annual Acquisition Research Symposium to be held May 12-13, 2010 in Monterey, California. U.S. Government or Federal Rights License					
14. 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.					
15. SUBJECT TERMS					
16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT unclassified	b. ABSTRACT unclassified	c. THIS PAGE unclassified			

The research presented at the symposium was supported by the Acquisition Chair of the Graduate School of Business & Public Policy at the Naval Postgraduate School.

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Exploring Acquisition Strategies for Adopting a Software Product Line

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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.



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 & Northrop, 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 & Northrop, 2002; Schmid & Verlage, 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.

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.

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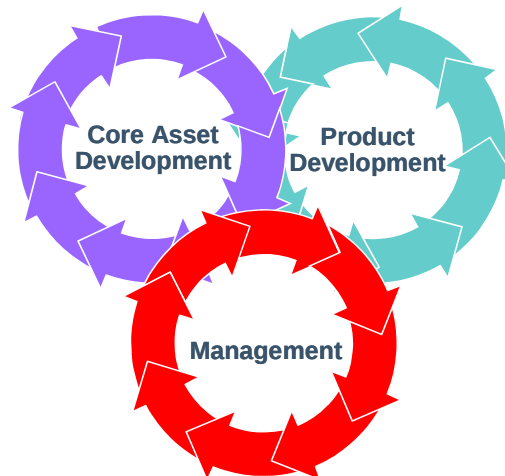


Figure 1. The Three Essential Product Line Activities



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.

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 & Northrop, 2002), and the latest version is available on the SEI Web site (Northrop & Clements, 2009).

Software Product Line Acquisition Challenges

Bergey, Fisher, and Jones 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, Fisher & Jones, 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*

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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 et al., 2003; Bergey, Cohen, Jones & Smith, 2004; Bergey, Cohen, Donohoe & Jones, 2005; Bergey & Cohen, 2006; and Bergey et al., 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.

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 & Capolongo, 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, Virtual, Constructive Integrating Architecture (LVC-IA) product line of the Army's PEO STRI (Bergey et al., 2009).

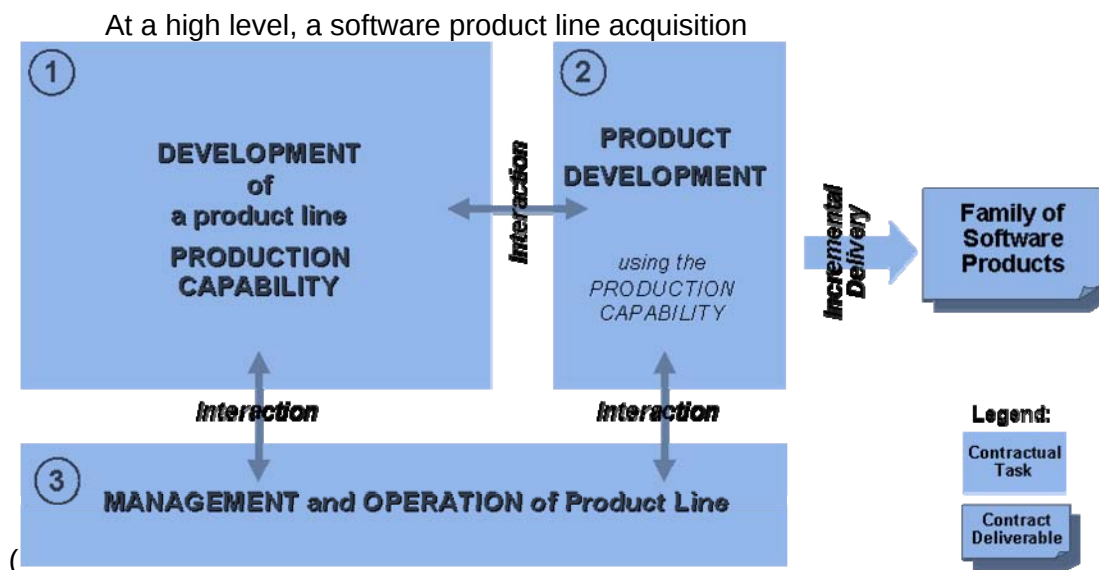
¹ This may include using the services of local Systems Engineering and Technical Assistance (SETA) contractors.



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 & Clements, 1996; Jensen, 2007) and Strategy 2 (Cohen, Dunn & Soule, 2002; and Cohen & Capolongo, 2007). Strategy 3 offers potentially huge rewards but is the most challenging to execute. However, several success stories have been reported (Bergey et al., 2009; Bergey, Cohen, Donohoe & Jones, 2010).

Contractual Tasks for a Software Product Line Acquisition



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

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



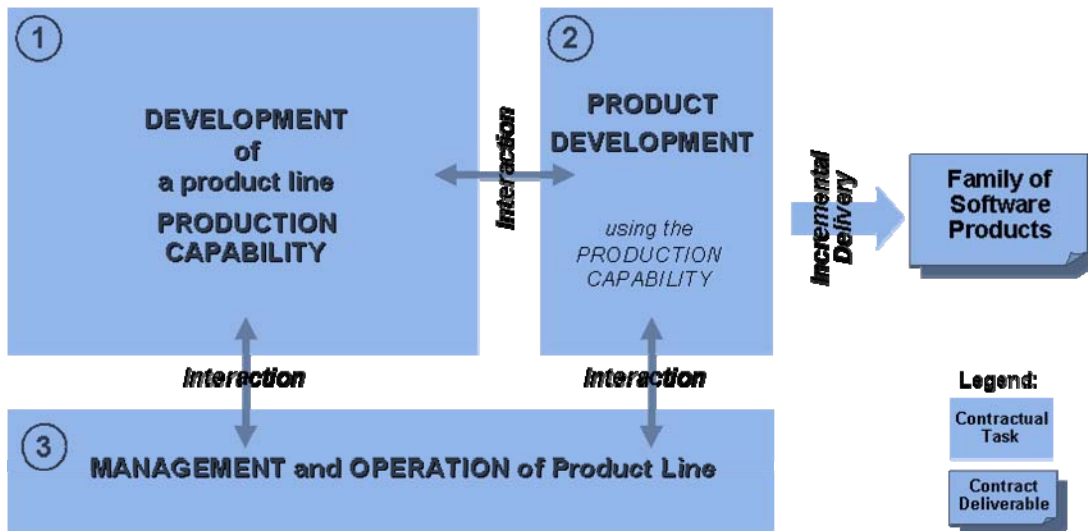


Figure 2. Three Major Contractual Tasks for a Software Product Line Acquisition

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 & McGregor, 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.

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?

Error! Reference source not found. shows an example of an enterprise view that corresponds to Acquisition Strategy 3 (described in Section 0). 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.



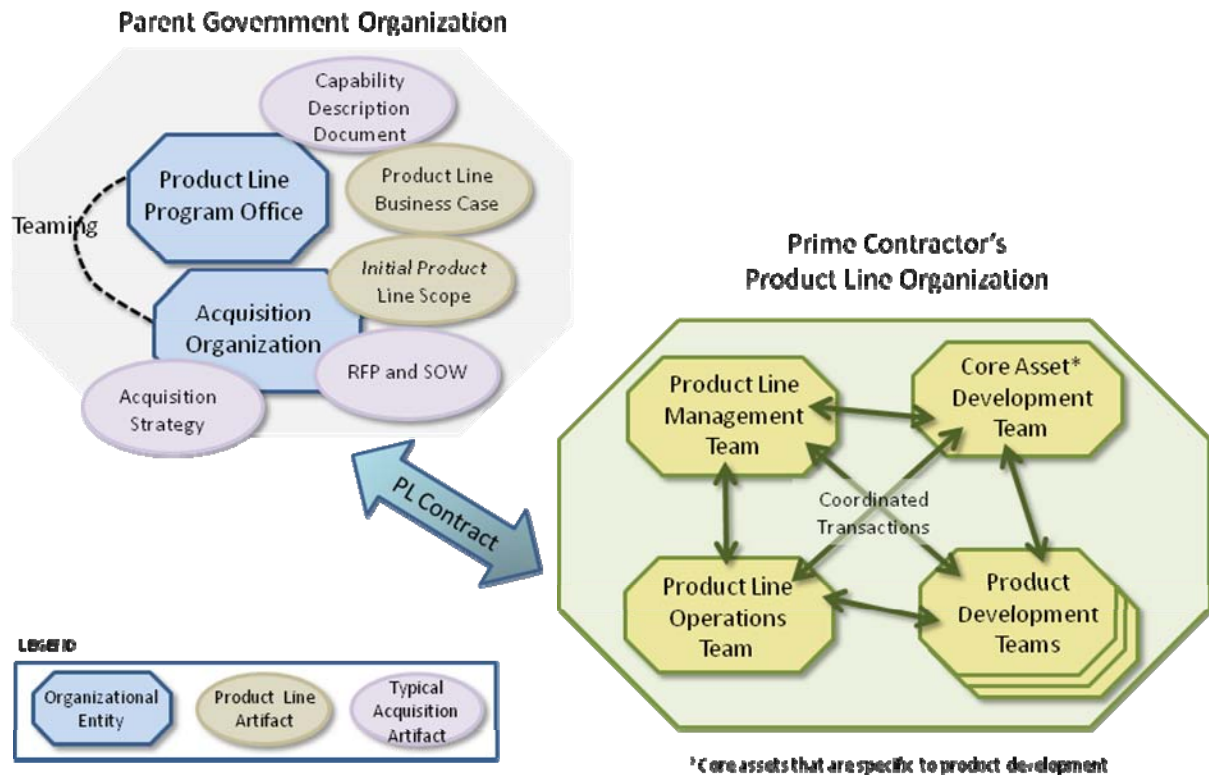


Figure 3. Sample Enterprise View of a Product Line Acquisition

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 **Error! Reference source not found.** 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.

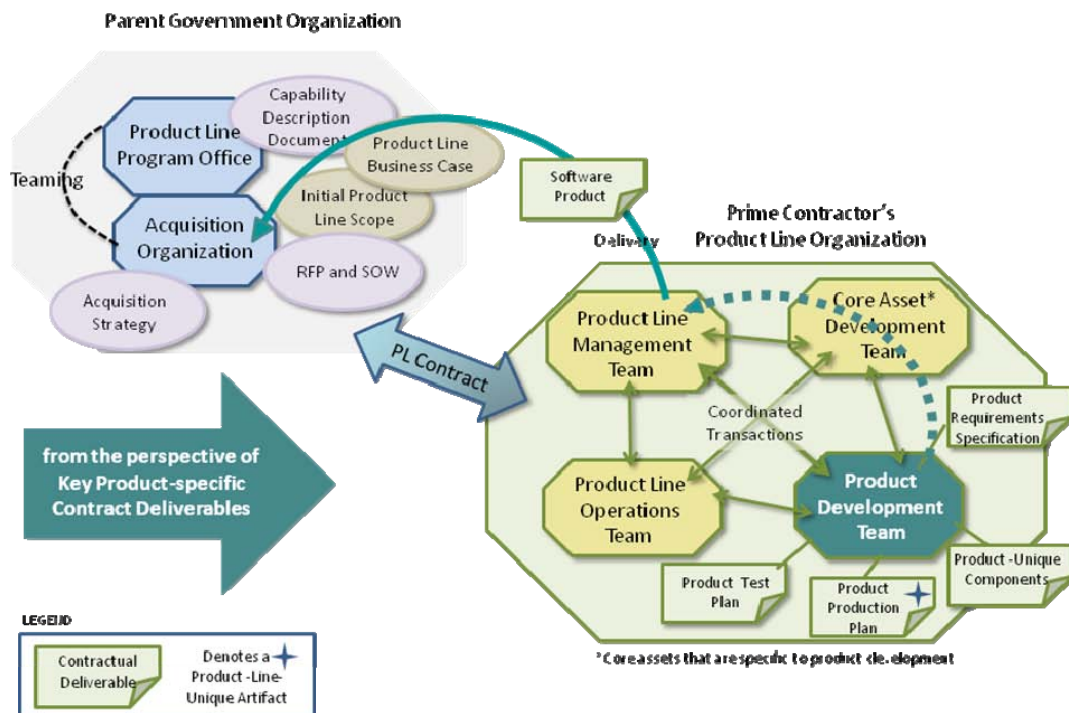


Figure 4. A View of a Product Development Team Using the Product Line Production Capability

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.

A Customer View of Software Product Line Acquisition

Error! Reference source not found. 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.

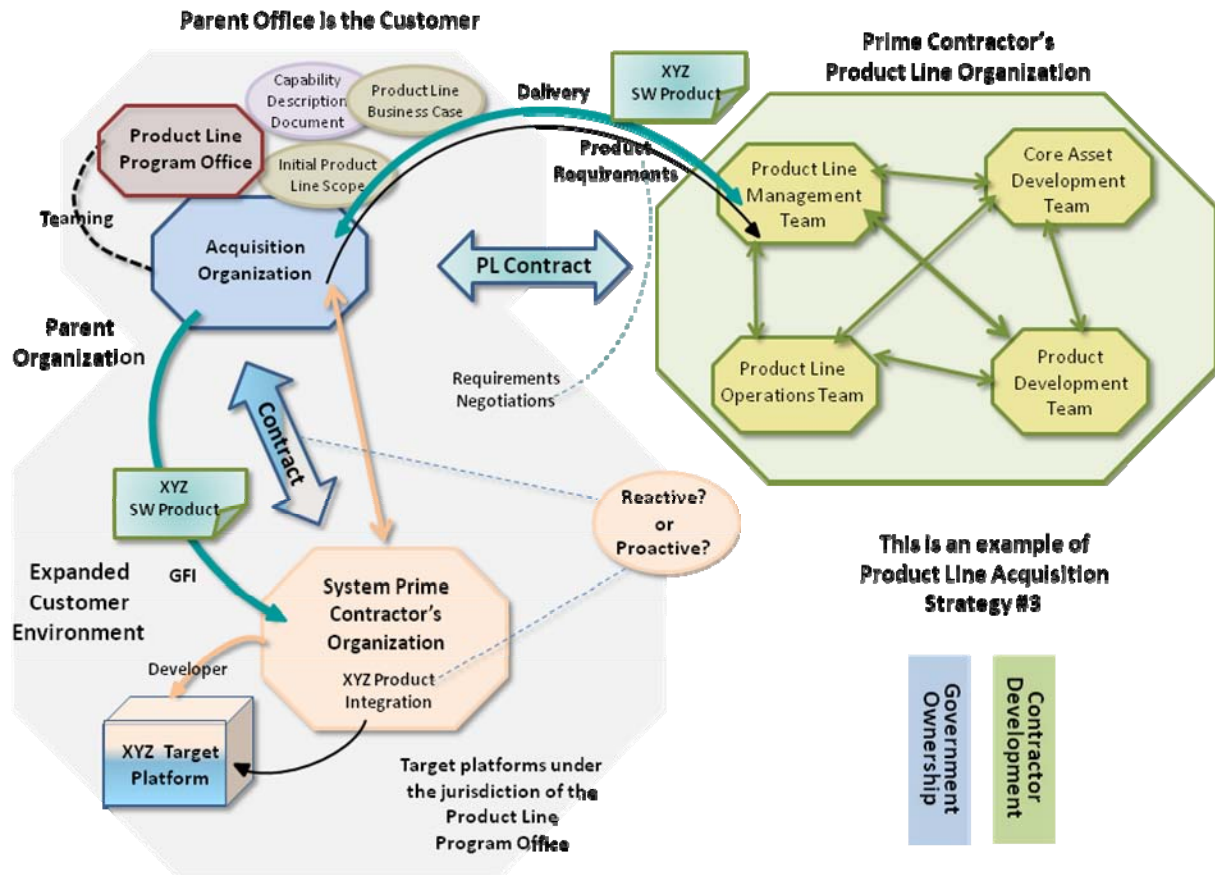


Figure 5. Simplest Case of Customer Interaction with Product Line Developer

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 **Error! Reference source not found.** between the *parent organization* and the *expanded customer environment*. In this context, the arrows shown in **Error! Reference source not found.** 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:

2. The program office analyzes and specifies the new product requirements (in conjunction with its acquisition organization and the contractor responsible for the target system).
3. The program office tasks the product line contractor with developing a new product (in accordance with the negotiated product requirements).
4. The product line contractor develops the new product and delivers it to the program office.
5. 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.



6. The target system contractor appropriately integrates the product into the target system.
7. 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 the *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.

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 a acquiring a software product line
- creating a sample *contract data requirements list (CDRL)* and *data item descriptions (DIDs)* for key software product line deliverables

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.



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Exploring Acquisition Strategies for a Software Product Line

John Bergey
Larry Jones
11-13 May 2010

7th Annual Acquisition Research Symposium
Naval Postgraduate School, Monterey, CA

Software Engineering Institute
Carnegie Mellon University
Pittsburgh, PA 15213

Sponsored by the US Department of Defense

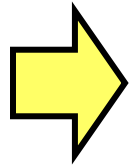


Software Engineering Institute

Carnegie Mellon

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Presentation Topics



Software Product Line Basics

Software Product Line Acquisition Challenges

Product Line Acquisition Strategies

An Enterprise View of a Product Line Acquisition

- Organizing a product line production capability
- Product development using the product line production capability

Summary



What Is A Software Product Line?

Software Product Lines:

“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]

In an Acquisition Context?

Acquisition:

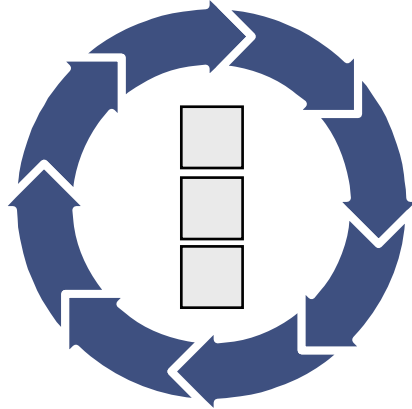
“The process of **obtaining products and services through contracting**. Contracting includes purchasing, buying, commissioning, licensing, leasing, and procuring of designated supplies and services via a formal written agreement.”

[Bergey and Fisher 1999]

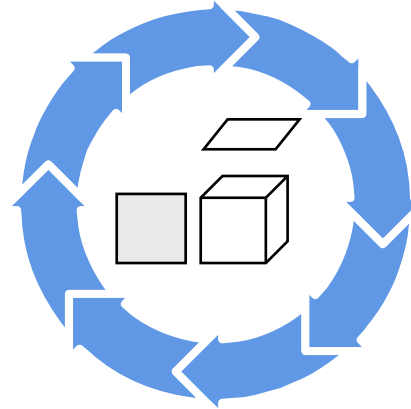


The Key Concepts

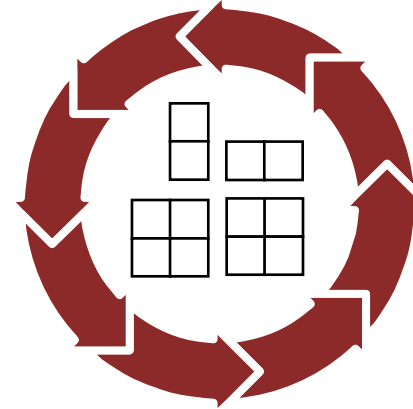
**Use of a core
asset base**



in production



**of a related
set of products**



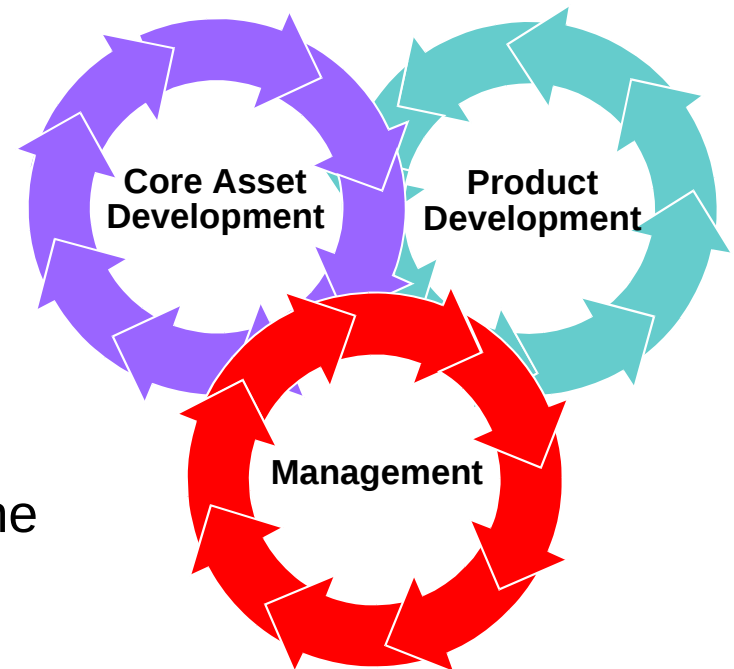
Three Essential Activities

All three activities are interrelated and highly iterative.

There is no “first” activity.

- In some contexts, existing products are mined for core assets.
- In others, core assets may be developed or acquired for future use.

There is a strong feedback loop between the core assets and the products.



Strong management at multiple levels is needed throughout.

Management oversees core asset and product development.

Management orchestrates all activities and processes needed to make the three essential activities work together.



Software Product Lines Value Proposition

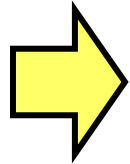
The systematic use of software product line practices results in significant organizational benefits including

- increased quality
 - by as much as 10x
- decreased cost
 - by as much as 60%
- decreased labor needs
 - by as much as 87%
- decreased time to market (to field, to launch...)
 - by as much as 98%
- ability to move into new markets
 - in months, not years



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Traditional Contracting vs. Product Line Acquisition

Traditional contracting is **most suited to** efforts that

- are well understood and have no unprecedented aspects
- are based on prior experience and well understood cost history data
- are based on predetermined quantity, schedule, and funding
- are well bounded – i.e., involve a fixed set of tasks and traditional deliverables in a well defined context
- have fixed and well understood requirements
- involve familiar practices and processes
- are likely to involve minimal changes or redirection

Product line acquisitions may present challenges to traditional contracting.



Traditional Contracting vs. Product Line Acquisition

Traditional contracting is **most suited to** efforts that

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- are based on prior experience and with enough history data
- are based on predetermined quantities
- are well bounded – i.e., involve traditional deliverables in a well defined manner
- have fixed and well understood requirements
- involve familiar practices and processes
- are likely to involve minimal changes or redirection

While these factors may prove troublesome for any acquisition, none of these are showstoppers.

Product line acquisitions may present challenges to traditional contracting



Specific Product Line Acquisition Challenges

Product lines focus on meeting the needs of multiple programs and target systems that transcend multiple platforms and developers.

These aspects may exacerbate product line acquisition because

- DoD's **acquisition policies and infrastructure** are still largely predicated on acquiring '**one-of-a-kind**' stovepiped systems.
- **Planning** a family of software products that rely on a common development effort is not a traditional DoD acquisition paradigm.
- No institutionalized means exist for **funding** the development and sustainment of a product line **across multiple programs**.
- **Program offices** are **not appropriately incentivized** to adopt a product line approach.
- **Contractors** are **not suitably incentivized** to participate in **collaborative** product line development and sustainment efforts.
- Adopting a product line approach may force the government to assume **system integration responsibility**.



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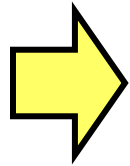
The "takeaway" is that programmatic issues – not technical issues – are the impediments to widespread adoption of product line practices in the DoD.



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Two Fundamental Ways for a DoD Program to Initiate a Product Line Acquisition

Reactive

Desired product line initiative/activities/tasks are conducted **opportunistically** and performed **in situ** under an existing contract.

Proactive

Desired product line initiative/activities/tasks are **preplanned** and **integrated up front** in a request for proposal (RFP) for a system (or software) acquisition.



Three Basic Acquisition Strategies for Acquiring Products via a Product Line Approach

1. **Commission a supplier to develop a specific product (or products) using its own proprietary product line.**

This strategy involves acquiring products directly from a supplier who has an existing product line and a demonstrated capability to build products in the domain of interest.

Contractor
Ownership

Existing
Product Line

2. **Commission a government organization to develop a product line production capability and build specific products.**

This strategy involves acquiring a completely government-owned product line using the in-house capabilities of a designated government acquisition organization.

Government
Ownership

Government
Development

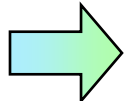
3. **Commission a supplier to develop a product line production capability and build specific products.**

This strategy involves acquiring a complete product line production capability and developing derivative products through contracting with one or more suppliers.

Government
Ownership

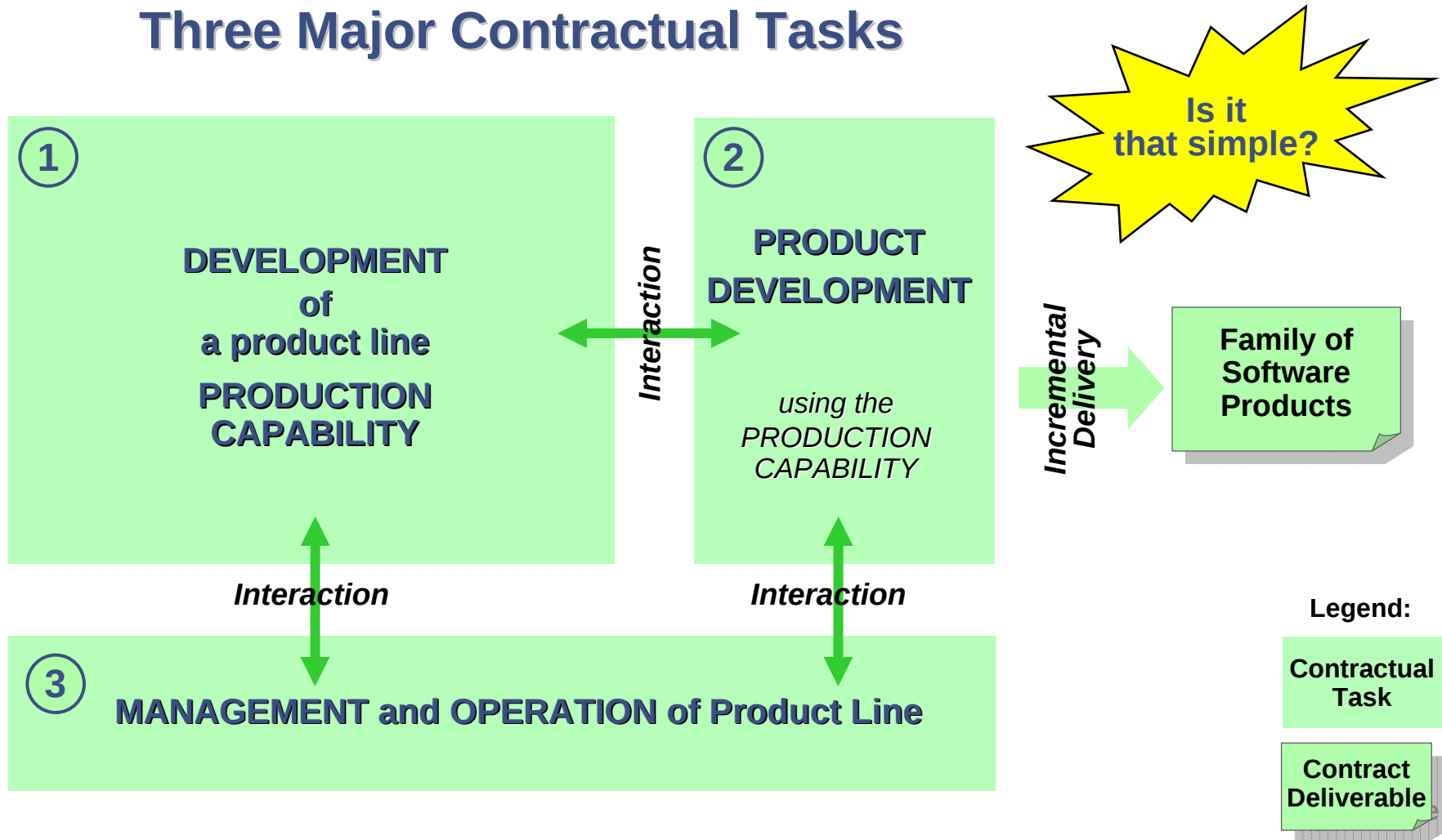
Contractor
Development

Presentation
Focus



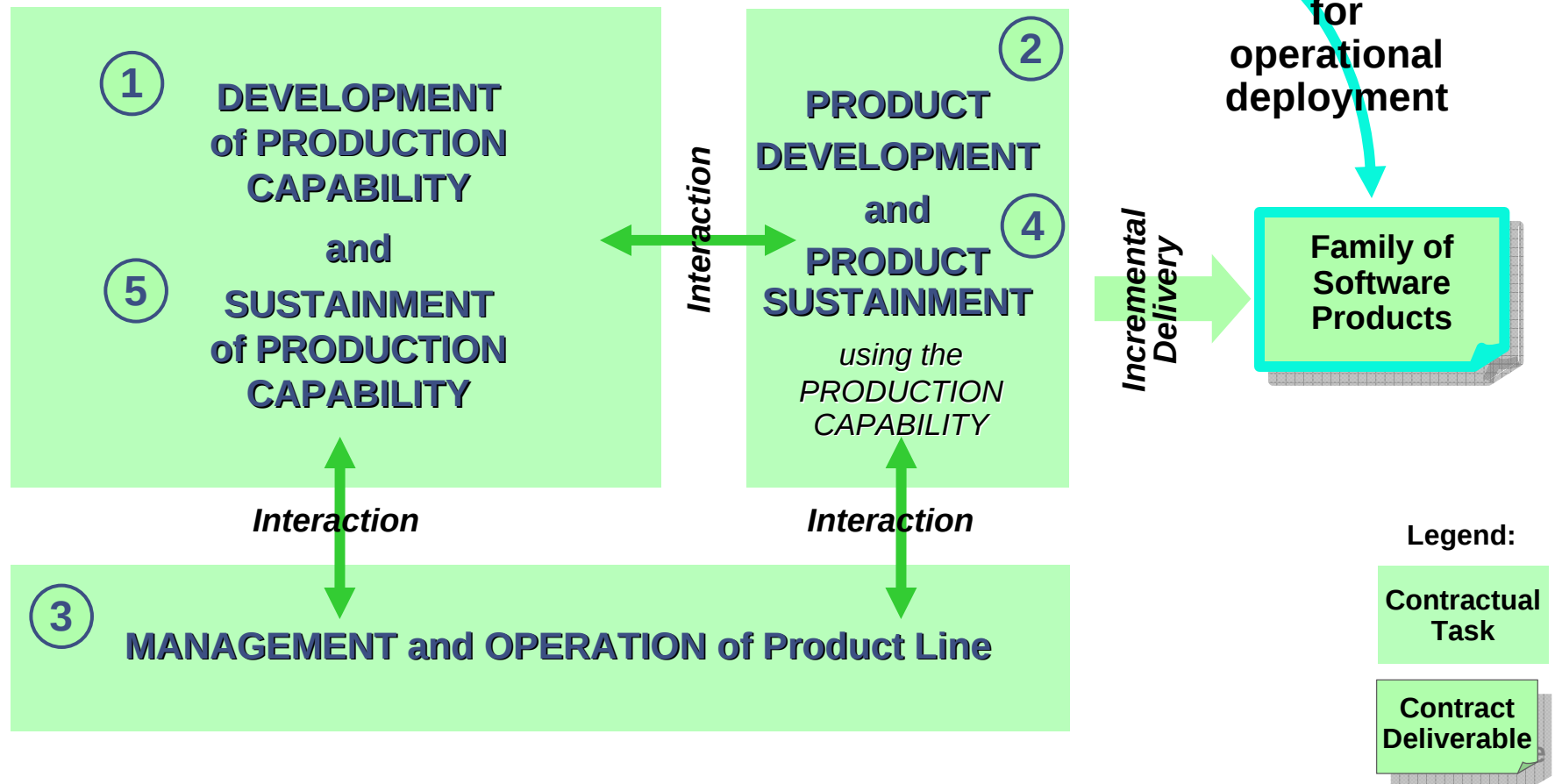
Overview: Software Product Line Acquisition

Three Major Contractual Tasks



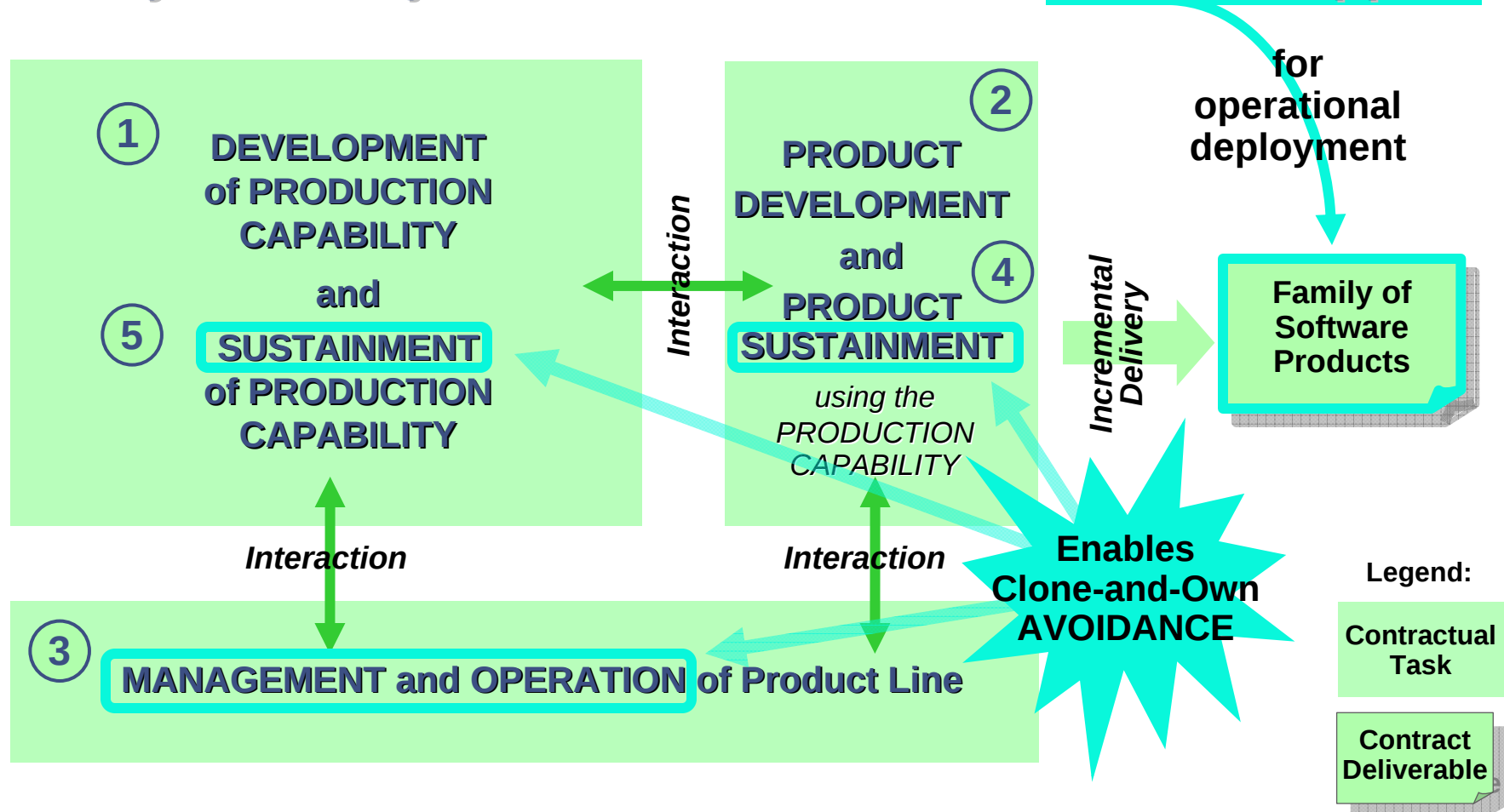
Overview: Software Product Line Acquisition

Reality: Five Major Contractual Tasks to Provide Support



Overview: Software Product Line Acquisition

Reality: Five Major Contractual Tasks to Provide Support

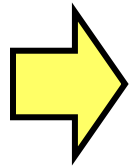


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Establishing the Product Line Context

The government acquisition organization has the responsibility for establishing the **product-related context** for the product line.

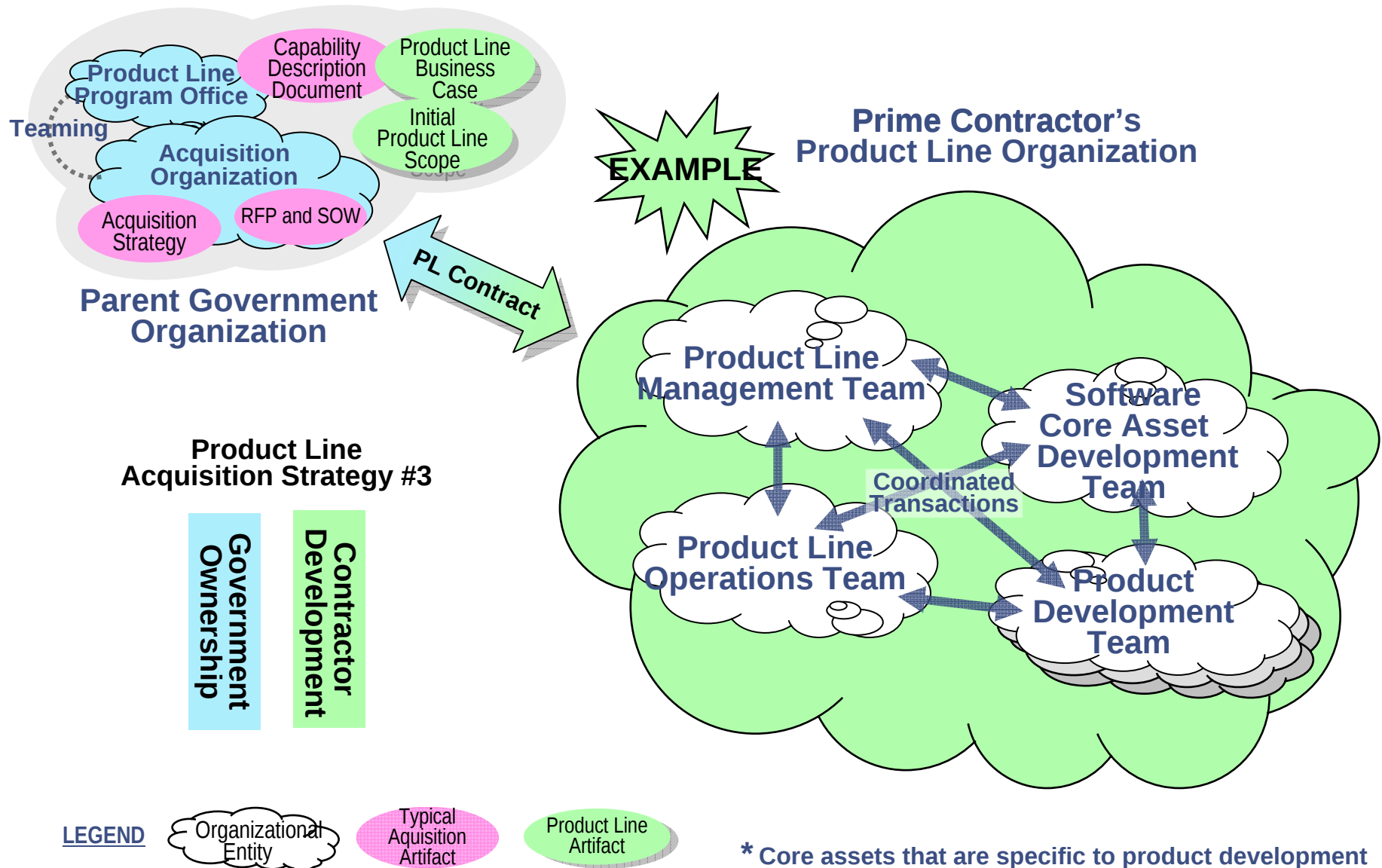
- What are we buying?
- What is the scope of the product line?
- What are the funding and schedule constraints?

The government acquisition organization has the responsibility for establishing the **organization-related context** for the product line.

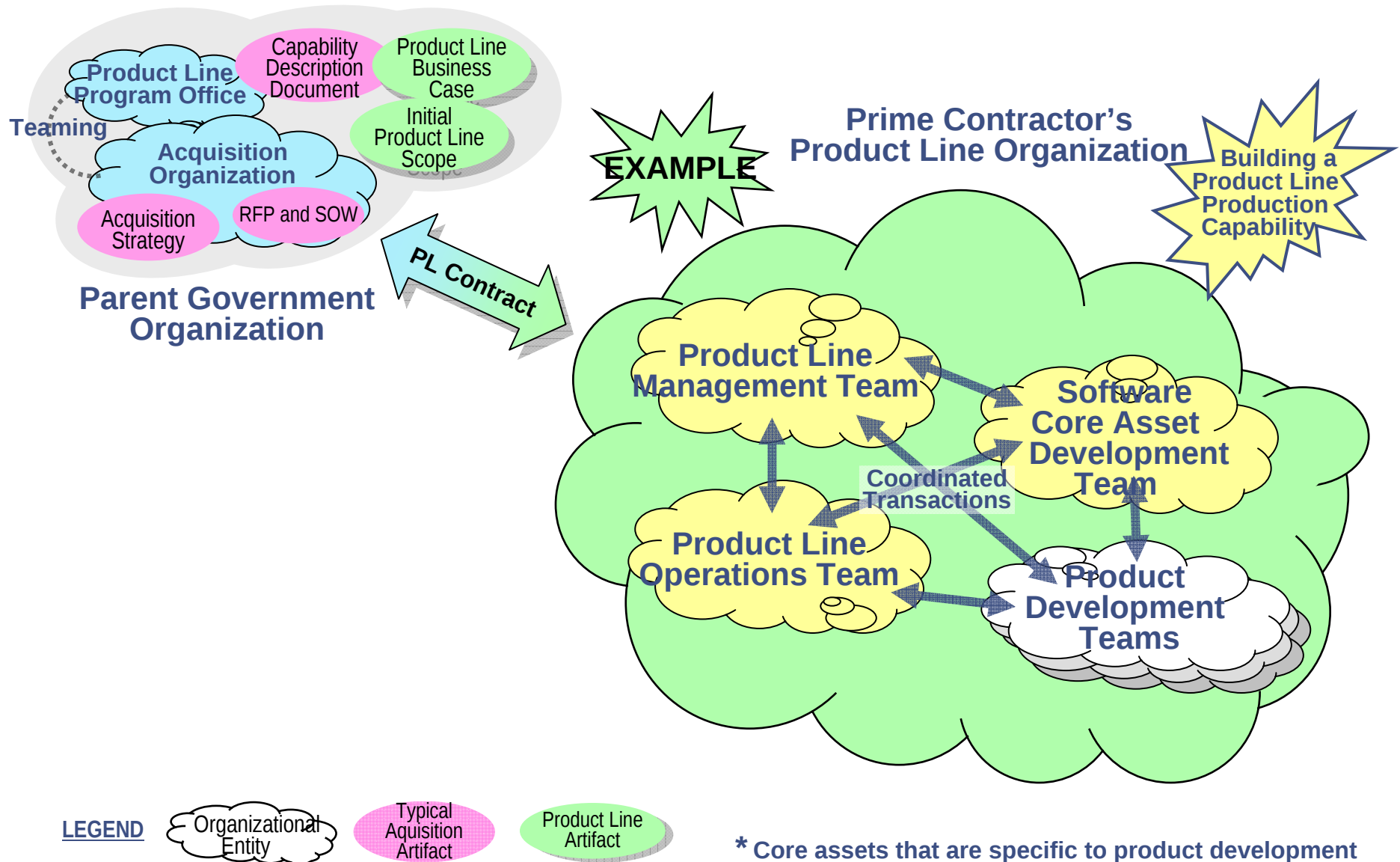
- What other organizations will be involved?
- What will be their roles and responsibilities?
- How do we plan, organize and operate the product line effort from an enterprise perspective? For example,
 - How will customer interface management be handled?
 - How can external product developers be accommodated?



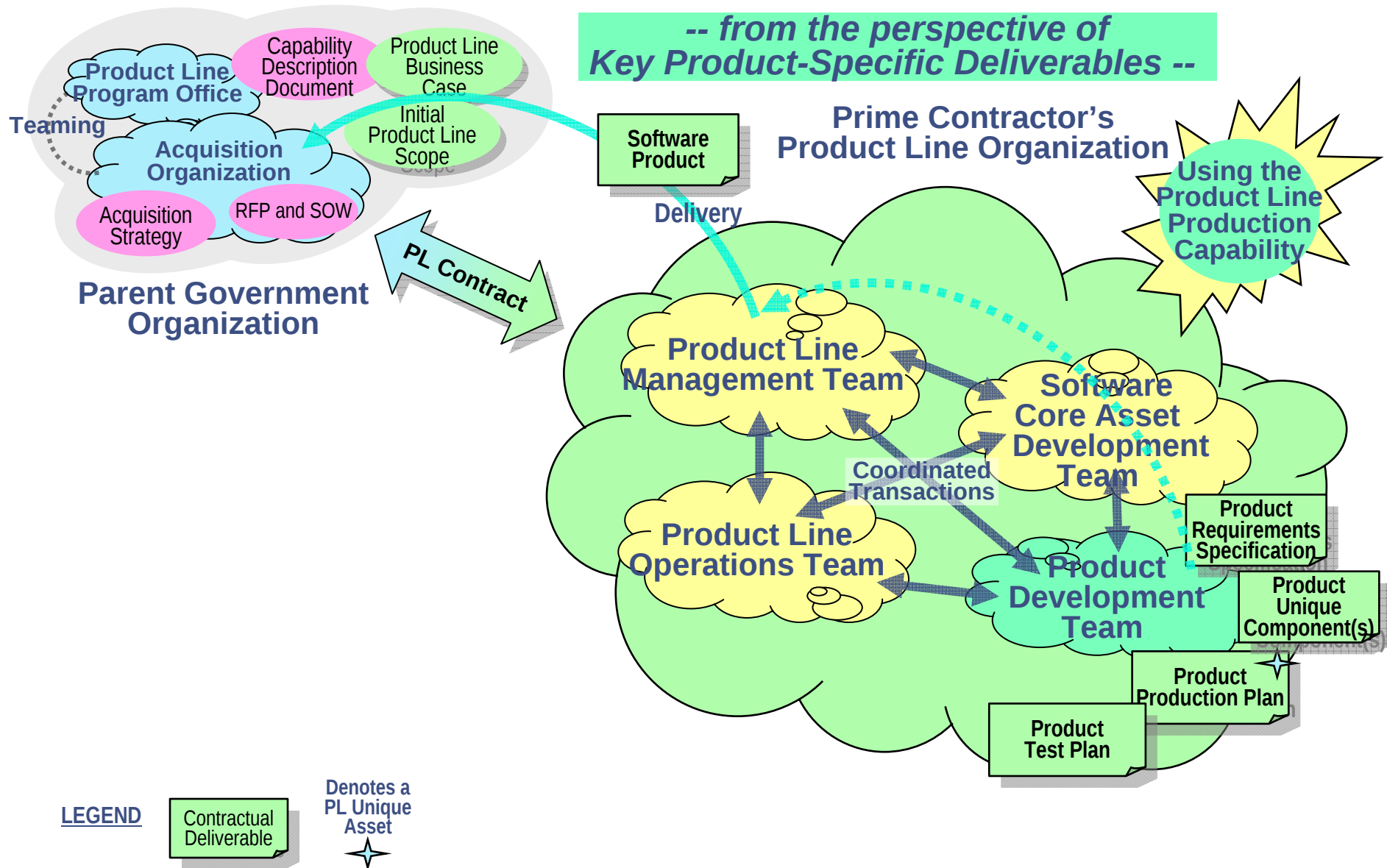
Enterprise View of a Product Line Acquisition



Enterprise View of a Product Line Acquisition



Enterprise View of a Product Line Acquisition



Presentation Topics

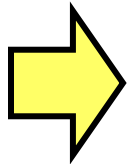
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Summary

Carefully choosing an appropriate product line acquisition strategy is essential to ensure the selected approach is

- consistent with stakeholders' expectations
- a good fit with the acquirer's resources and technical skills

Considering product line acquisition from an enterprise point of view is useful for

- identifying and understanding how stakeholder involvement is managed
- understanding stakeholder interactions and interdependencies and defining specific roles and responsibilities
- stimulating discussion, analyzing different “acquisition threads” (i.e., scenarios), 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 already fielded?



Questions



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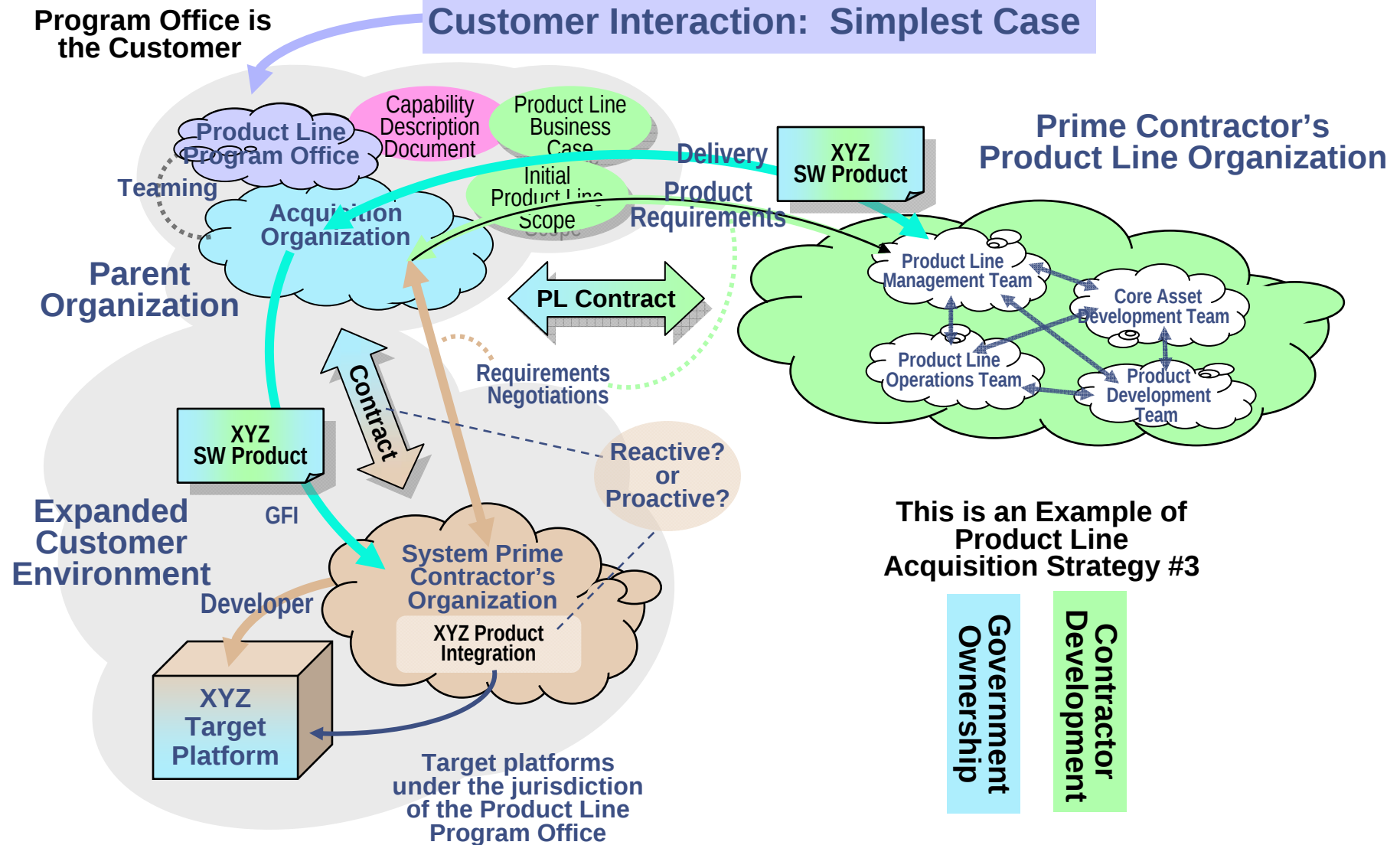
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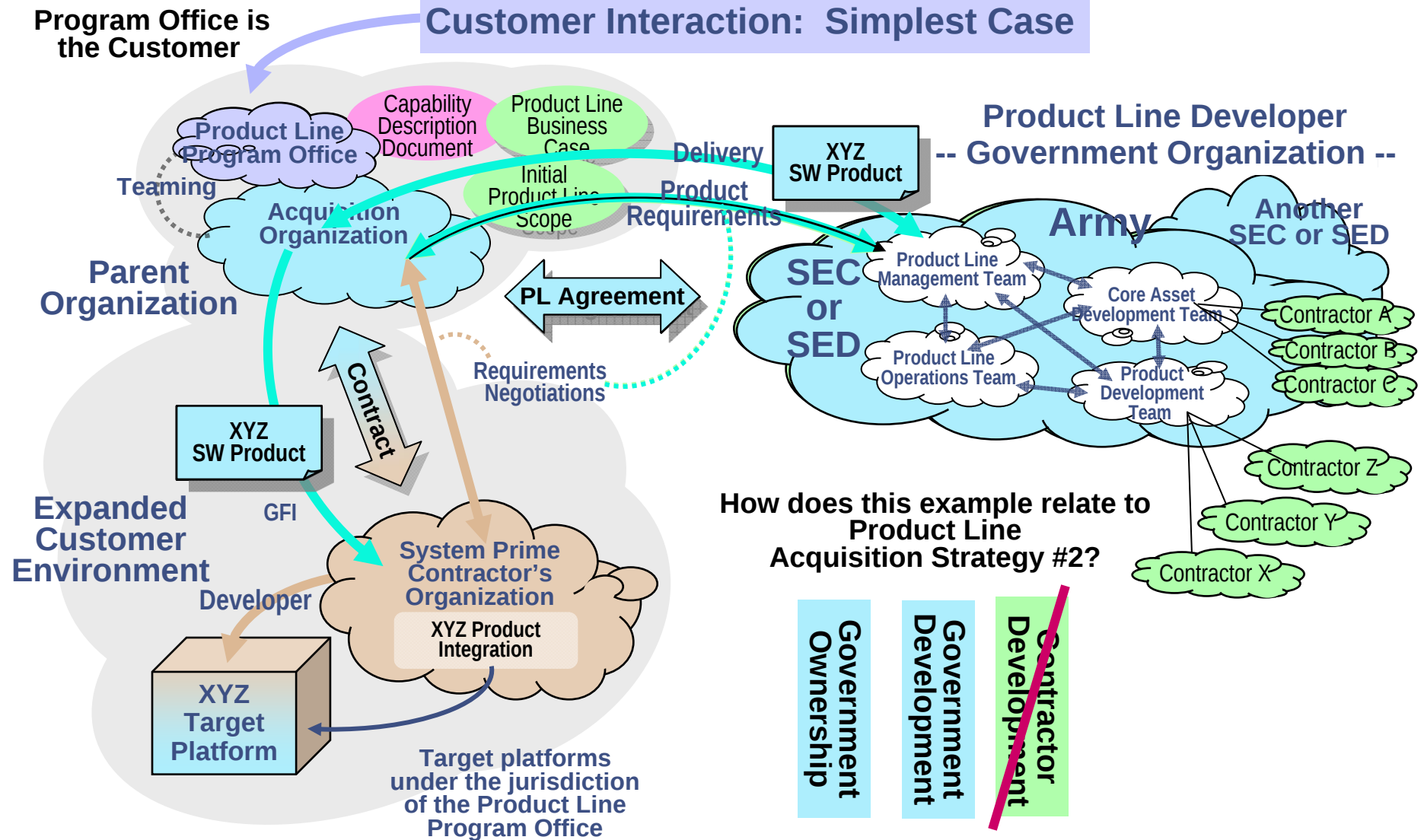
Backup Slides



Customer View of a Product Line Acquisition



Customer View of a Product Line Acquisition



Customer View of a Product Line Acquisition

Customer Interaction: General Case

