

A Strategy for Component Product Lines: Report 3: Component Product Line Governance

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Table of Contents

1	Introduction	1
1.1	The Purpose of This Report	1
1.2	The Importance of Component Product Line Governance	1
1.3	Product Line Governance in Context of Legacy Government Processes	2
1.4	The Structure of This Report	2
2	Component Product Line Ecosystem	3
2.1	Component Product Line—Relevant Stakeholder Organizations	3
2.1.1	Government Organization(s)	3
2.1.2	Marketplace Organizations	5
2.2	Component Product Line—Implementation Artifacts	6
2.2.1	Component Product Line Specification Model—CPLSM	6
2.2.2	Component Product Line Instances—Models and Designs	7
2.2.3	Component Product Line Physical Instances—Hardware and Software	7
2.3	Component Product Line—Process Artifacts	8
2.3.1	Component Product Line Opportunities List	8
2.3.2	Component Product Line Inventory	8
2.3.3	Component Product Line Dashboard	8
2.3.4	Component Product Line Change Request / Order	8
2.4	Roles and Responsibilities	8
2.4.1	Component Product Line Champion	8
2.4.2	Component Product Line Manager	9
2.4.3	Component Product Line Specification Modeler/Modeling Team	9
2.4.4	Component Designer—Component Product Line Designer	10
2.4.5	Component Instance Designer	10
2.4.6	Component Implementer	11
2.4.7	Component Verification and Validation Assessor	11
2.4.8	Weapon Systems Integrator	12
3	Scenarios	13
3.1	Create New Component Product Line	13
3.1.1	Assess Marketplace for Legacy Component Offerings	14
3.1.2	Incorporate the New Component into the Product Line Organization	14
3.2	Modify and/or Update an Existing Component Product Line	14
3.2.1	Respecting Boundaries	16
3.2.2	Identifying Change Drivers	17
3.2.3	Retiring a Legacy Product Line	18
3.3	Applying Component Product Lines to a Weapons System	18
4	CPL Governance Processes	20
4.1	Marketplace Engagement	20
4.1.1	Development of CPLSMs	20
4.1.2	Communicating Government Needs to the Marketplace	20
4.2	Supplier Analysis and Qualification	20
4.3	Strategic Processes	21
4.3.1	Technology Surveying	21
4.3.2	Identification of Candidate Components	21
4.3.3	Alignment of Component Product Line Practice with Program Office Needs	21
4.4	Tactical Processes	22

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4.4.1	Establishing, Maintaining and Prioritizing the Backlog	22
4.4.2	Component Product Line Configuration Control Board (CCB)	22
4.4.3	Justifying the CPL Effort	22

List of Figures

Figure 1: Relevant Component Product Line Stakeholders of the Ecosystem

3

List of Tables

Table 1: Possible Sources of Change and Product Line Mitigations

18

1 Introduction

1.1 The Purpose of This Report

This report provides guidance for the community involved with developing and sustaining product lines of components used by the U.S. government. It complements, and should be read together with, the complementary SEI Component Product Line (CPL) special reports: *A Strategy for Component Product Lines: Report 1: Scoping, Objectives, and Rationale* and *A Strategy for Component Product Lines: Report 2: Specification Modeling for Components in a Component Product Line*. Whereas the strategy outlines the overall intent and game plan for implementing a component product line approach (the “what” and the “why”), this governance report provides critical insight into “how” the authors envision a successful initiative to be implemented. For additional guidance related to specific implementation in a model-based environment, consult the modeling report. Some of the scenarios used in this report to illustrate Component Product Line Governance are also used in the modeling report.

1.2 The Importance of Component Product Line Governance

It is important to recognize that CPLs have been tried before in U.S. government organizations. The results have not been successful. The most important reason for this lack of success is that when the government funds the acquisition of a weapon system, it provides the funding to a program office, not the component product line organization. It is a governance action for the program office to use the product line approach to support its acquisition. The decision whether to use its (appropriated) funding to support the CPL initiative is either mandated by the overarching organization, collaboratively agreed on, or, possibly, rejected by the acquisition program.

The initial cost to the government to develop and acquire a product line component is more than that for a component providing single-use functionality. The extra cost is primarily non-recurring; that is, it only occurs the first time the component is procured and should be viewed by the acquisition community as an “investment” in the component. It comes from identifying points of variation (i.e., feature sets) and developing notional instances of the component. These tasks would not be performed if the component was not planned as a product line component. The investment is justified because the component is intended for use on more than one platform. The return on this investment derives from (1) reduced effort to update the component when requirements change, because the change was anticipated and planned for in the initial design, and (2) reduced cost for future procurements of the component, because most of the design has already been done, and the component is typically already in production, which will likely lead to reduced sustainment costs.

The main objection an acquisition program office will have to procuring a product line component is that it is not a program requirement to invest in a component to reduce the component’s cost for future programs or in the future reduction of costs for changes. To overcome this obstacle, the overarching acquisition community will need to acknowledge that lead platforms may incur more cost up front (than follow-on programs) and provide some resources to soften the blow. One way for the community to put this into practice would be to establish an organization whose primary

focus is to manage CPL opportunities. Throughout this paper, we refer to this new organization as the CPL Organization. We envision this group to be led by a highly motivated, knowledgeable, and capable individual, the Product Line Champion. The processes defined by this organization, and the adherence of the stakeholders to these processes, are what will define the success of the CPL initiative. Collectively, this is what we call “governance.”

Governance is neither simple nor static. In general, issues that arise during the implementation of the CPL initiative will need to be addressed, requiring changes to the initial plan. This document serves as the starting point and forum for the discussions that will ultimately lead to the “to-be” processes (i.e., the governance for the component product lines).

1.3 Product Line Governance in Context of Legacy Government Processes

Experienced readers will note the similarity of the issues addressed in the context of product line governance with other, more traditional government practices. While there may be areas of overlap, it is *not* our intention in this paper to suggest that we need to reinvent the wheel. An example of this is supply chain management, which is employed to deal with the acquisition of components, where challenges such as obsolescence might exist.

While the success of the product line initiative may depend on effective supply chain management processes (in fact, the response by the supply chain management process to a product line issue may dominate its resolution), the CPL initiative adds a new dimension. The CPL perspective focuses on decision making that affects the commonality and variability aspects of the product line component and its instances, while supply chain issues broadly deal with situations that impact the supply of a component. So, the effect of issue resolution for a product line component may be more complicated than a single instance of a component.

Another example might involve qualification of a supplier to deliver a product line component or product line component instance. In this case, there is plenty of experience in the government to qualify suppliers, but possibly the product line aspect of the qualification may require some new skills, or collaboration (with a product line organization). It would be expected that the current process is updated to deal with the new context.

1.4 The Structure of This Report

Section 2 describes the anticipated ecosystem for CPLs. This includes a description of (1) organizations that are directly involved in product line activities, (2) expected artifacts for the product lines, (3) product line roles and responsibilities, and (4) additional stakeholders. Section 3 outlines some scenarios that illustrate the challenges likely to require governance. Section 4 describes the processes that will need to be developed to enable effective governance. The processes are categorized to enable some key aspect of the product line implementation (e.g., supplier analysis and qualification, or technology surveying).

2 Component Product Line Ecosystem

As shown in Figure 1, a government-industry grouping of stakeholder organizations (the ecosystem) collaborates by performing roles (with responsibilities) to create artifacts that realize the strategy for establishing CPLs and applying them to the acquisition and integration of weapon systems.

The component product line ecosystem is responsible for identifying CPL needs and specifying, using, and sustaining the CPLs. This responsibility includes evaluating existing components (to be included in a product line), instantiating new CPLs (that may be part of an acquired weapons system), and assuring the CPLs are properly vetted, used, and sustained.

2.1 Component Product Line—Relevant Stakeholder Organizations

The notion of a “relevant” stakeholder is one that participates actively in some significant portion of the lifecycle activities of the CPL. These stakeholders will have a direct impact on important aspects of the resulting components (e.g., functionality, modifiability, and points of variation). We have chosen to organize these stakeholders broadly (see Figure 1) as being either representatives of government or representatives of “the marketplace.”

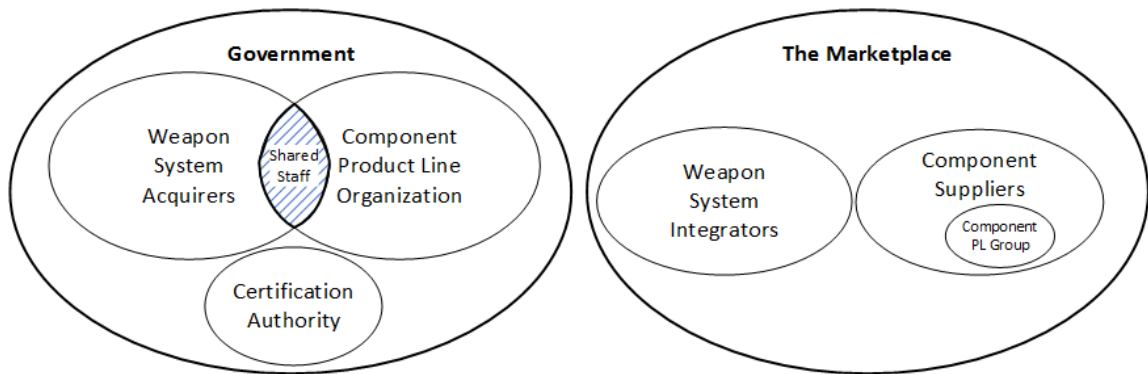


Figure 1: Relevant Component Product Line Stakeholders of the Ecosystem

2.1.1 Government Organization(s)

The government is a key player in the implementation of CPLs. The CPL Organization is the government-led and staffed organization that is the primary government stakeholder responsible for the product lines. The product line components are intended to be used by the government acquisition and sustainment communities as a key enabler of the modular, open system approach (MOSA). We expect that the component product line organization will need to exist independent of weapon system acquisition programs. However, for the endeavor to be successful, these acquisition programs will need to cooperate with the policies, processes and direction established by the CPL Organization, and the CPL Organization needs to be cognizant and responsive to the acquisition program needs. For existing components, product offices already exist that could be used

to manage CPLs. For these existing components, the weapon system program office is expected to simply contract with the assigned CPL Product Office.

The more interesting case is when a new CPL is under consideration. The governance mechanism envisioned for this situation is illustrated in the diagram as “Shared Staff.” A trained representative of the CPL Organization staff would work as the Product Line Manager for the new component, while being matrixed (or embedded) as a member of the lead platform acquisition program. While this approach provides the required coordination between the CPL Organization and the Weapon System Program Office, it will also put pressure on the embedded staff, as there will be times when the weapon system acquisition program office’s goals may appear to conflict with the product line’s goals, and the shared staff member will be stuck in the middle of the conflict. We expect this type of situation to be resolved by the Product Line Champion and the Acquisition Project Manager. It is important to recognize that the issue might have been completely missed (to the detriment of the product line) if the shared staff did not exist. Some of these situations will be elaborated in Section 3, Scenarios.

2.1.1.1 Component Product Line Organization

The CPL Organization sets the agenda for the product line activities. Most government organizations do not have such an organization, so the way this organization is implemented could vary. For example, the organization could be just a single person, the Product Line Champion, who would rely on other organizational entities to perform the CPL activities. On the other hand, the organization could be fully staffed by the Champion, and many of the other CPL roles (as defined in Section 2.4, Roles and Responsibilities). In all cases, the CPL Organization is led by the Product Line Champion, who plays a pivotal role in the success of the overall product line initiative.

The CPL Organization must do the following:

- Establish the CPL strategy.
- Define the government CPL processes.
- Establish the government CPL artifacts.
- Work with other stakeholders to establish how to implement the strategy.
- Regularly assess its plans and processes to determine adherence, process issues, and to identify opportunities to improve the processes.
- Develop the CPL specification models (CPLSMs).
- Perform verification and validation (V&V) of the CPL artifacts.

In some cases, the government may provide the overarching CPL practices.

2.1.1.2 Weapon System Acquirer

The weapon system acquirer, or program office (PO), is a relevant stakeholder and the primary customer of the CPL Organization. The PO may provide staff to perform the roles that support the

CPL Organization. For example, if a new CPL component is planned to be used on a particular acquisition, the PO staff would play a pivotal role in the product line processes. In this case, the PO staff member performing these tasks would be trained by the CPL Organization and would be performing that portion of their job for the CPL Organization.

2.1.1.3 Certification Authority

The certification authority, whether for airworthiness, safety, or security, provides subject matter expertise relative to its area of responsibility. The certifiers play a critical role in the product line approach, as a significant amount of benefit for the product line is involved in “inherited validation” (i.e., the product line component comes into the system “pre-qualified,” reducing the overall scope of certification for the system).

2.1.2 Marketplace Organizations

The marketplace represents the supply side of the product line components. To be specific, this includes the actual component suppliers, and the major system integrators (that use the components in their systems). More broadly, suppliers might extend to new potential suppliers, possibly with component offerings that have been used in other domains, or suppliers of commercial off-the-shelf (COTS) products.

2.1.2.1 Component and Component Product Line Suppliers

Component suppliers design, manufacture, and sustain product components. Some of these suppliers may also provide the product line practices (e.g., identifying points of variation, feature sets, and managing configurations) for the component instances. No matter the category of supplier, we expect there to be ongoing collaboration between the CPL Organization (government) and the supplier(s) (marketplace). In general, suppliers fall into one of the following categories:

- Developers of components (instances) that conform to a CPL specification: These components would meet some core set of capabilities, as well as one or more feature sets (accommodating some anticipated variation).
- Creators of the component product line design that complies with all planned feature sets and points of variation: Normally, these would be the same suppliers as the ones who provide the components, but not in all cases.

In general, a component supplier accepts government furnished information (GFI) in the form of CPL specification models. The component suppliers are responsible for the component design and manufacture, and fulfill the following tasks:

- Perform component development activities, design, and manufacture, leading to fully compliant components that are ready for integration.
- Identify opportunities for new components from prior implementations and reconfigure and modify them as necessary to produce the new component instances that conform to CPLSMs.
- Create a component production and test capability (for all component lifecycle activities).

- In some cases, perform overarching CPL practices (e.g., identify points of variation and manage changes) in coordination with the CPL Organization.

Note: These role descriptions assume that the component supplier is not the weapon system integrator (i.e., that the tier 1 [integrator] to tier 2 or tier 3 supplier relationship is maintained). The content of the CPLSMs (e.g., capabilities, feature sets, and enterprise architecture requirements) must address the integrator-supplier relationships.

2.1.2.2 Weapon Systems Integrators

Weapon system integrators, or prime contractors, are usually the recipient of the supplier's components. In some cases, the integrator may also be the component supplier. The weapon systems integrators do the following:

- Confirm that a selected component addresses the complete feature set required for the weapon system and collaborates with the CPL Organization and the supplier(s) to address capability gaps or adaptations.
- Review and apply documentation to assure that the appropriate system environment exists (or can be provided) to integrate the component.
- Perform risk mitigation by virtually integrating the weapon system component models (including model analyses) and performing system-wide analysis.
- Test components in unit and integration testing settings to assess their integration readiness.
- Complete all system integration, testing, and other activities leading to certification and delivery of the weapon system that address the system specification of a weapon system product acquisition organization.

When suppliers are developing new components, the weapon system integrator participates with the government to perform assessments of the evolving component. These assessments include, but are not limited to, artifact review, design reviews, test readiness reviews, and acceptance testing. There may be issues with the protection of the supplier's intellectual property (IP) that will need to be resolved as part of providing this necessary oversight.

2.2 Component Product Line—Implementation Artifacts

What follows are the notional artifacts expected to be needed to support the lifecycle needs of the CPL ecosystem.

2.2.1 Component Product Line Specification Model—CPLSM

Once the decision is made to move ahead with developing a CPL, the CPLSM is the first significant artifact for the product line. The CPLSM is developed and modified under the auspices of the CPL Organization. It is the primary means for communicating to the various relevant stakeholders the requirements and expectations for the components and for the variations of the components that form the product line, as exemplified in the following scenarios:

- Weapon system (WS) acquisition programs collaborate with the product line organization to create new (or update existing) CPLSMs to meet the needs of their acquisition. Generally, a

new instance requires an *instance specification model*, which may or may not change the parent CPLSM. We expect that the WS and the CPL Organizations would collaborate to create the new instance specification.

- Weapon system integrators and component suppliers might use the CPLSM as a diagnostic to verify and validate that their components are compliant. If they are not fully compliant, the CPLSM could be used to illustrate what parts of the CPLSM they are not compliant with, which might be viewed as trade space by the stakeholders.

Note: Throughout this document (and the other documents in the series), we use the term “the 150% model” to describe the CPLSM. To be clear, 150% is an arbitrary number: It is used to convey the notion that there is more in the product line specification than in any single instance.

Note: The intended scope of the CPLSM is to provide adequate information for an acquirer to specify and procure the component, as opposed to providing adequate information to build the component.

Note: Refer to the accompanying technical paper, Modeling for Components in a Component Product Line, for specific guidance on creating a CPLSM.

2.2.2 Component Product Line Instances—Models and Designs

Models, most notably the component instance model, and designs are essential artifacts. They are the primary means of communicating the planned implementation of the component (by the supplier).

In addition to the normal configuration management practices employed by the marketplace suppliers, we expect that the CPL Organization will keep an inventory of model-based representations of component instances. The models will primarily be used to verify compliance; initially instance models will be verified against the CPLSM, and later the developed hardware and software will be verified against the instance models. Models will also be used to perform various types of model-based analyses, as required, to support the needs of the stakeholders (e.g., integrability, modifiability, latency, and bandwidth). There are potential issues with proprietary data that might impact the usefulness of the models, reducing critical component functions to simple black boxes defined by external interfaces.

Component instances and their corresponding CPL designs and architectures are also expected to be inventoried by the component product line organization. Intellectual property considerations need to be balanced with the need for the government to preserve a production capability for the component.

2.2.3 Component Product Line Physical Instances—Hardware and Software

Physical instances of the component hardware and software, most importantly the software (along with the environment needed to modify and/or upgrade the software), must be capable of being sustained. The sustainment will likely be performed by the component supplier, but there may be cases where the CPL Organization or the weapon system integrator might need to perform the sustainment with organic resources.

2.3 Component Product Line—Process Artifacts

2.3.1 Component Product Line Opportunities List

The CPL Organization will establish and maintain a list of product line opportunities for possible inclusion into the group of components that are managed as product line components. The opportunities will usually result in new CPL specification models or requests for information (RFIs) that are used to “test the waters” of the marketplace. However, the list might also be viewed as the CPL Organization’s “backlog,” and therefore would also include potential changes to the current product line component baselines.

2.3.2 Component Product Line Inventory

The CPL Organization will establish and maintain a master list of component product lines and their related instances. This list will include important data (availability, used by, etc.) about the product line to help users determine whether there are suitable components to meet their needs. This data is expected to be defined by the CPL Organization.

2.3.3 Component Product Line Dashboard

The CPL dashboard provides a summary of status regarding the component product line activities. This may include risks and opportunities as well as normal status for ongoing work. The details of the dashboard features (e.g., metrics, format) is left to the CPL Organization.

2.3.4 Component Product Line Change Request / Order

The standard means to propose modifications to the current product line component baselines (e.g., new feature sets), or to propose new potential opportunities, or to retire obsolete baselines will be a product component line change request form. This would be the standard form used when conducting a configuration management meeting.

2.4 Roles and Responsibilities

2.4.1 Component Product Line Champion

The Product Line Champion is responsible for establishing and sustaining the CPLs that produce components for the weapons systems. The champion must communicate the CPL vision and make the CPL strategy happen. The champion must do the following:

- Identify and appropriate the resources needed to establish and sustain the product line organization.
- Establish the product line governance processes.
- Chair the configuration management board.
- Assign responsibility for specific product lines to a **Product Line Manager**.
- Collaborate with product line managers to identify and qualify **component suppliers**.
- Establish the culture needed to maintain the CPL strategy by applying incentives or penalties, as necessary, to **integrators** and **acquirers**.

2.4.2 Component Product Line Manager

The CPL Manager serves as the lead for one or more CPLs. The manager establishes acceptance criteria for all component artifacts that enter the marketplace and maintains relationships across the enterprise-wide CPL ecosystem. Collaborating with acquirers, integrators, and suppliers, the CPL Manager helps evaluate and select components for their weapon systems. This collaboration examines specifications, appropriate feature and variation sets, and existing components from the marketplace. CPL Managers will resource the correct expertise to do the following:

- Survey weapon system requirements to identify and scope capabilities to be captured as CPL opportunities.
- Develop plans, budgets, and schedules for each CPL they are responsible for.
- Follow the governance processes established by the product line champion.
- Develop and maintain the specification model for their CPLs.
- Identify and manage points of variation for their CPLs.
- Assess candidate components (coming from suppliers) for conformance to the specification models.
- Work with government acquisition programs to support evaluation and selection of components for weapon systems.
- Support weapon system acquirers by ensuring that the selected product line components are available as needed to perform weapon system integration and testing.
- Provide feedback from the component integrator to the modelers and the suppliers.
- Manage product line specifications and configurations, identifying enhancements and upgrades as appropriate to maintain and sustain the CPLs.
- Establish intellectual property rights for the U.S. government (USG).

2.4.3 Component Product Line Specification Modeler/Modeling Team

The CPL specification modeler/modeling team develops specifications (in the form of models, text, drawings, etc.) that satisfy capability requirements. Specifications models are the primary means for communicating the government intent, so the role of the modeler is critical to the success of the CPL project. Because the models are intended to apply to multiple platforms, the modeling team must proactively seek out areas of commonality and planned points of variation that satisfy all of the relevant stakeholder's needs. In general, the modeler/modeling team will do the following:

- Capture the scope and capabilities in models that represent use cases, any use restrictions, operational behavior and functionality, lifecycle, and logistics constraints.
- Illustrate anticipated variation across the product line that affects feature set selection in the following areas: functionality, resource utilization, deployment variations, error handling, and cybersecurity.

- Utilize government and industry standards, weapon system specifications, existing component documentation, and component systems as guidance in specification of model content. Content may be requirements for all component variants or individual variations selected for a specific feature set.

Note: Modelers may not have all the information or expertise to document what is listed in this paragraph. They may need to refer to a systems or software engineer.

2.4.4 Component Designer—Component Product Line Designer

The CPL designer develops the design of the component product line, incorporating the intended points of variation into the product line design. This role may be thought of as the CPL design architect. Through the CPL design artifacts, the designer must convey the common elements of the component design along with the specified points of variability so that the component instance supplier can visualize the potential variants that may need to be provided. This role may be performed by the supplier of the component, although it might also be performed by a “product line” design agent. The component product line design is needed by the component instance designer to create an instance of the product line component design and/or to evaluate COTS/GOTS. The key for the product line component design team is to be able to correctly anticipate areas of concern across the lifecycle (e.g., evolving threats, obsolescence, reuse, and sustainment) and incorporate these as points of variation in the product line design.

The CPL design may incorporate models. There may be special skills required for the developers of the models:

- Models may be used as an aide to the product design process (i.e., to capture design alternatives and rationale for design decision selection, especially with respect to product lines).
- Models may need to comply with standards (e.g., Future Airborne Capability Environment [FACE[®]], Architecture Analysis & Design Language [AADL], and/or GFI templates) to support downstream analysis and translation.
- Component product designers may use models to aid with physical integration by representing component interfaces.
- Models may provide preliminary evidence of design verification for certification and accreditation.

2.4.5 Component Instance Designer

The component instance designer takes the CPL design output in conjunction with the component instance specification model and creates component design instances to support specific weapons systems acquisitions. The component instance designer plays a pivotal role in the CPL governance activities:

- The component instance designer is the first “consumer” of the CPL design and will likely be the focal point for changes.

- The component instance designer interprets the product line design, assessing the core functionality along with the required feature sets to produce the design of the component instance.

Component instance designers need to provide their design deliverables to Product Line Managers and/or weapon system integrators as required to support downstream integration and V&V activities for the weapon system.

2.4.6 Component Implementer

The component implementer produces (builds and tests) component instances. As stated above, the implementer may or may not be the component designer. The component implementer will do the following:

- Establish the production facilities to produce and test the component, potentially incorporating product line concepts into the manufacturing and testing facilities.
- Build and verify the component instance is compliant with its specifications.
- Perform preliminary integration, using model-based methods, or with an integrator-provided test harness, or with their own test harness.
- Test the component, as required.

2.4.7 Component Verification and Validation Assessor

The component product line organization will be responsible for V&V. This role is particularly important because of the desire for the components to contribute to MOSA objectives of reuse, extension, and interoperability. V&V occurs throughout the lifecycle, but more attention should be given to the product line V&V during the design, as it will be very difficult to modify the product line after design is completed, especially to accommodate new (i.e., unplanned) points of variation that may be challenging.

2.4.7.1 Product V&V

The most basic form of V&V is for the product itself. There is nothing special about the product V&V; the scope of the V&V should include assessment of conformance to the component instance models, designs, and implementations, along with specific variation points and feature sets.

2.4.7.2 Product Line V&V

The more interesting form of V&V is for the product line itself. The design of the CPL will have planned points of variation, and the product line V&V must provide evidence that these are accommodated for in the planned product variants, even if they have not yet been built. From a governance perspective, this may be particularly challenging, as a specific program may not care about the effort to accommodate product line points of variation, especially if it puts its schedule at risk.

2.4.7.3 Certification and Accreditation

CPLs may provide opportunities to streamline certification and accreditation (e.g., airworthiness and cyber). This is because the certification authority may be able to split its process between the

shared elements of the product line (i.e., evidence that could be inherited from instance to instance) and the unique variations of each product instance. Naturally, it is assumed that each instance would be reviewed completely, but the evidence for the common elements of the CPL might be presented in such a way that the authority's effort could be minimized.

2.4.8 Weapon Systems Integrator

The weapon systems (WS) integrator is responsible for integrating the product line component into the weapon system. There are many implied responsibilities for the WS integrator, as they need to participate in the technical review activities for the component(s). We expect that there will be more than one WS integrator for any given product line. The integrator plays a pivotal role in the CPL process, as they provide the environment needed for successful product integration. This may be provided to the component supplier in the form of a product integration model or a shared integration laboratory facility (such as an HIL or SIL) where the component supplier can perform preliminary integration activities. The WS integrator is also expected to provide feedback to the Product Line Manager on integration lessons learned to inform a potential new set of features that improve integrability. The integrator also provides feedback for CPL improvement and sustainment.

We envision two primary contexts for interactions between the WS integrator, the component supplier, the WS acquirer, and the CPL Organization:

- The WS integrator acquires the component from the component supplier as part of its project. In this case, the WS integrator is responsible for incorporating the needs of the WS acquirer and the CPL Organization into its subcontractor acquisition contract. Additionally, acquisition regulations limit the involvement of the government, so there is increased responsibility for the WS integrator to act in the interest of the government.
- The WS integrator is provided the component by the government (primarily via the WS acquirer) as government furnished equipment (GFE). In this case, the government is responsible for addressing the needs of the WS integrator and the CPL Organization into its component acquisition contract. Acquisition regulations would not limit the involvement of the WS integrator, but the government must explicitly involve the WS integrator as necessary to ensure that the component integrates as expected and provides the component's expected functionality within the context of the WS platform.

3 Scenarios

These scenarios are specifically chosen to illustrate aspects of the product line lifecycle in which governance may be an issue. Collectively, the scenarios should logically lead to a coherent set of activities, or processes, that will need to be established to enable a successful product line approach.

3.1 Create New Component Product Line

An acquisition program is reviewing its updated technical requirements and has determined that there is a new required capability to actively measure the center of gravity of an airborne platform. The program office is investigating the feasibility of this capability being provided as a CPL.

The acquisition program knows of the product line initiative, because one of its staff members was trained by the product line organization and understands how to initiate the product line investigation. The acquisition program works with the product line organization to establish a list of those components that are potentially product line components, and it regularly coordinates the status of its needs with the product line organization.

For this new capability, the acquisition program requests the product line organization to determine whether (or not) the center of gravity component should become a product line component. The product line organization acts on behalf of the acquisition program to perform specific tasks in support of these product line components.

Note: If the CPL Organization has an embedded resource within the acquisition program assigned to make the assessment, it may not appear as if the CPL Organization is doing anything to support this determination. However, the assigned resource will be following the processes of the CPL Organization and, to the extent practicable, will be reporting to the CPL Organization while performing the investigation.

The product line organization will act as requested by the acquisition program within a specified amount of time, depending on priority. The standard response would be to perform an assessment of the capability's suitability as a product line component. This assessment would be based on criteria (actual criteria is TBD by the product line organization, but notional criteria might include: (1) commonality across platforms, (2) existence of a similar COTS product in the marketplace, and (3) others).

To support this assessment, it is likely that the product line organization would collaborate with the acquisition program to develop a draft set of technical requirements and use this as part of an RFI to test the marketplace for legacy component offerings. Once the marketplace has responded to the RFI, the product line organization will decide on whether to incorporate this new component into the inventory set of product line components.

We expect the evaluation process to produce an artifact, either a paper or a briefing, that provides the outcome, along with the rationale for the decision. This would be prepared by the product line organization and provided to the acquisition program.

3.1.1 Assess Marketplace for Legacy Component Offerings

As part of the process to stand up a new CPL, the product line organization may need to assess (or survey) the marketplace to identify potential components that would serve as a starting point for the product line. For example, a pre-existing component might incorporate a superior approach to providing the component's functional capability, but lack some non-functional attributes (e.g., performance, security, safety, and modifiability). In this case, the product line organization may consider using this pre-existing component as a starting point for its product line component.

The organization that has produced the existing component may be averse to modifying it as needed to support the product line approach required by the product line organization. It may be necessary for the product line organization to award a separate contract to an organization willing to adapt and support the component. Additionally, there may be intellectual property issues whenever multiple companies are involved in collaboration, and these should be worked out as part of the contracting process.

In any case, it is the responsibility of the product line organization to establish the path forward to develop the new CPL. In the context of the component, this might involve developing component simulations to be used for evaluation purposes. It might be the case that there is a CPL evaluation facility that is used to support the assessment. The role of the product line organization is to critically assess the available alternatives and determine the best approach for this component.

3.1.2 Incorporate the New Component into the Product Line Organization

When a new product line component has been specified and acquired, it will need to be made available to the other platforms. The primary mechanism for communicating the status of product line components is via the component product line inventory artifact.

3.2 Modify and/or Update an Existing Component Product Line

There are many potential reasons to modify (or update) an existing product line component. A few of these are described below. The most common reasons for requiring an update to the product line component relate to capability enhancements and/or obsolescence. In some cases, the update will be needed to support the product line itself.

For example, a weapon system may have a new requirement. When this requirement is analyzed, the resolution may be to investigate a modification to an existing product line component that would change a common feature to a variable feature. In this context, the change management process for the product line component requires unusual skill from the CPL Organization, as it is possible that implementing the update might impact current users of the product line component. The CPL Organization must act as a communicator of the potential change to the stakeholder community. In addition to raising the awareness of the change to the community, existing con-

sumers may have other needs that might be addressed with the same update. So, the CPL Organization not only needs to assess the technical feasibility, but it must also provide the programmatic coordination needed to make the stakeholder community aware of the change and how the change is planned to be implemented.

What is important to recognize is that the integrity of the product line is the primary consideration when determining how to manage the changes. That means that the change management team should prioritize technical solutions that preserve the product line, limiting unnecessary branching (cloning).

In many ways, this scenario resembles a traditional configuration management (CM) process, but the two differ significantly when it comes to the effectivity of the change. By their very nature, product lines are intended to be used by multiple stakeholders, so addressing the various stakeholder needs as part of the change management process is extremely important. One way to think about this concept is to relate it to the way that COTS products are managed. A COTS product may be upgraded by its developer, but not all users of the product may choose to adopt the updated product right away (or ever). Conversely, at some point the updated COTS product must be adopted, as the prior component version has become obsolete or other versions have become unsupported. At this point, the COTS provider stops supporting that customer, no matter how much they pay. (An example of this phenomenon is the use of Windows NT by the U.S. government.) In the case of COTS product lines, the end user in this example would lose the support for the product from the product line organization.

Implicit in this discussion is all the activity that led to this point. It should not be the case that any consumer is caught off guard by a component product line modification. The weapon system product line consumer has options: (1) it may be able to transition to a different component supplier taking advantage of the CPLSM as a reference, or (2) it has to live with the obsolete component. It is incumbent on the product line organization to communicate status and do what it can to support its consumers.

In the context of governance, there will be challenges with managing the technical scope and the effectivity of the change and with determining how the change will be funded. This requires a thorough understanding of where the product line component is used within the enterprise, what version is being used by each platform, and other aspects of the change relevant to the platforms.

In the context of *product line governance*, the technical review of the proposed change will be focused on commonality and feature sets of the (existing and proposed new) product configurations.

To illustrate, suppose Platform A uses component X. Platform B also uses component X. Platform C would like to use component X for its new system, but its requirement for component X includes a new data element that would change one of the feature sets of component X, and the interface between component X and the platform. The new data element is a result of a technology update to a sensor that is used by Platforms A and B; however, they do not have the requirement to update the feature set to their systems yet.

The product line governance action would be to determine the suitability of the change and recommend a path forward. This change recommendation, although primarily focused on supporting

the needs of Platform C, cannot be made in a vacuum. There may be potential implications for Platforms A and B. For example, the governing board may identify the updated sensor/data element as a point of variation for the product line. In this way, a configuration setting within the platform could allow the specification of the variant as part of an initialization step in the start-up of the platform. This would also provide the opportunity for both the prior and the updated components to be used on a platform, introducing potentially new platform configurations (that might require additional verification and validation as part of operational testing). Of course, Platforms A and B could choose not to incorporate the update into their platform. The key point is that the product line governance action provides a path forward for the other Platforms to evolve into the updated component. Without the involvement of product line governance, the component may be implemented as a unique component for Platform C, defeating the intent of the product line.

In general, we can imagine two alternative courses of action that might support this change:

- Accept the change, incorporating the new sensor/data element into the feature set for component X.
- Reject the change, forcing Platform C to either use the existing component X and supply the new data element on a new interface (or some other approach to incorporate the new data element).

Note that there are several factors that could sway the governance of this decision. It is essential that, as current consumers of component X, Platforms A and B partake part in the decision-making process. Here are some of these factors:

- There may be pressure on Platforms A and B to also adopt the updated feature set, anticipating an upcoming change to their requirements.
- There may be an upcoming unrelated change to component X, necessitating a new version anyway.
- Platforms A and B may be approaching end-of-life, and the timing might be right to retire the component, replacing it with the new component X¹.
- Platforms A and B are still compliant with component X, but if component X needs to be replaced or upgraded for another reason later, they should use the new feature set, component X¹.

3.2.1 Respecting Boundaries

This section describes a related scenario that illustrates alternative courses of action that the Governance Board would have for any potential change. The intent of the discussion is to point out that, when evaluating a change, there are implementation options, and the course of action that is recommended ought to be in line with the guidance that is explained in this section. It is especially important to understand and respect the boundaries that define the *essential* elements of the component product line and the system into which the component instance is integrated.

These essential elements are the

- essential functionality of the component product line (i.e., the *essence* of the component)

- context of the system that enables the component to perform fulfill its intended use
- connection of the component to the system

We use a simple example to illustrate this. Consider a navigation subsystem that requires position, navigation, and timing (PNT) information. The system integrator is using a Global Positioning System (GPS) device to provide this data. The system integrator has implemented a FACE conformant Transport Services Segment (TSS) to deliver the data from the component to the system. The system integrator has developed a GPS interface component to communicate with the GPS (e.g., start-up, shutdown, data processing, and diagnostics), and provide FACE conformant messages to the system as services.

To summarize, the product line component is the GPS device, the system context is the FACE TSS, and the connection of the component to the system is via a proprietary interface. Changes to the navigation subsystem might include (1) increased precision of position and time, (2) faster data rate, (3) update to the TSS, and (4) new shutdown sequence.

The critical role that governance plays is in the allocation of the work to implement the change. For example, let's assume that changes (1) and (2) are essential elements of the component and should be allocated to the product line component (also assume that the increased precision and faster data rates are not already optional configurable features of the GPS), because that is part of the component's essential scope. However, a system integrator might be able to mimic increased precision and faster data rates by adding computational elements (e.g., linear interpolation) to its interface component. While the implementation of the change (by the component supplier or system integrator) may appear to the consumer to be equally acceptable, the decision to allocate the change to the interface component would violate the functional boundary for the component. Although it may be more convenient for the system integrator to implement the change at the interface (in fact, it may be fine to implement at the interface *as an interim step*, as the update to the component might take a while to implement), the "right" way to implement the change would be to update the GPS component. The governance needs to recognize these considerations and act accordingly, especially in the case of product line components, where investment is made at the component level.

3.2.2 Identifying Change Drivers

Table 1 presents a partial list of potential sources of change for a component that may be useful for developing specific strategies for certain types of changes. These change sources can be used by the stakeholders to mitigate the impact of changes if they can be anticipated and planned for in the design of the component product line.

Table 1: Possible Sources of Change and Product Line Mitigations

Change Driver	Product Line Mitigation
Replacement of a component	Obsolescence: Anticipate the component elements that are likely to become obsolete and create variation points for them in the product line design.
Addition of external data input or service to a component	Anticipate the sensors most likely to change data inputs to a component and create variation points to allow for this change to be implemented with less effort.
Improved algorithm	Create architectural abstractions for the algorithms that allow them to be changed without any other impact to the component (e.g., ballistic calculation).
Mission function and/or operation	Anticipate future mission needs and provide variation points to the component to allow new mission requirements to be incorporated.
Fault handling and/or diagnostics processing	Identify variation points within maintenance methods (e.g., Built-In Tests).
Hardware or software environment updates	Anticipate the likely effect of changes to the environment (e.g., OS or infrastructure and build variation into the component to accommodate).

3.2.3 Retiring a Legacy Product Line

At some point the component will become obsolete and will be replaced by a new component that serves the same function. The media and media-reading devices that are used to play movies offer a simple illustration of this concept. VCRs were replaced by DVDs. Now very few people have DVD players: Most people are using cloud-based DVRs to record their content. These people now have unused devices sitting near their TVs and shelves loaded with old media. In the Department of Defense (DoD), the product lifespan for DoD components is much longer than it is in the commercial world; the pace of change is much slower.

The product line component processes ought to provide a built-in upgrade path because there is a natural refresh cycle that is part of the acquisition lifecycle. In addition to the change/modify scenario described above, new platforms will be created to replace old ones. When that happens, much of the new functionality will be similar to the old functionality. This should provide the environment needed to update obsolete technology.

3.3 Applying Component Product Lines to a Weapons System

A new Weapon System Program Office has been created. Even though the WS program is early in its lifecycle, long before final decisions will be made regarding specific components, the WS PM should be interfacing with the CPL Organization. The purpose of this collaboration is to identify potential opportunities for both organizations. The Program Office may not be aware of the product line offerings that are available to it. At the same time, the CPL Organization may get early insight into potential additions to existing product lines and may learn about opportunities for new components. Eventually, the WS program would include specific components as GFE, or have CPLSMs that would be included as GFI.

The CPL Organization will review the WS requirements and identify potential product lines (and feature sets) that might be applicable. Note that this engagement occurs very early in the lifecycle, prior to the establishment of any of the systems engineering baselines. Yet, the WS platform is a candidate CPL consumer, and will likely have similar component needs to other WS platforms in the Program Executive Office (PEO).

Some of the product lines will be applicable as-is; they already meet the needs of the platform. Other product lines may need to be modified. For example, a current component product line might have been designed to operate on a 1553 data bus. The new platform may be evaluating deterministic Ethernet data busses and be looking to transition to this new data transport mechanism.

Others may not yet exist and may be presented as opportunities to the CPL Organization. For example, there is a new requirement for the platform to interface with a data loader, requiring data logging and health management. There may be a preexisting CPLSM for such a device; if not, a CPLSM could be prepared by the CPL Organization. In either case, the WS acquirer would review the CPLSM and determine its suitability for the data logging and health management requirements. The CPLSM then becomes the technical specification that starts the acquisition of this new component.

4 CPL Governance Processes

This section describes the processes we envision for the CPL Organization to be instantiated to govern the component product lines. These processes have been described broadly in the scenarios, and many are implied by the artifacts and roles outlined above. At some level there will need to be collaboration among all of the processes by the government stakeholders, primarily the CPL Organization and the WS acquirers.

It is important re-emphasize that these processes must be viewed through a product line lens. For the most part, the processes already exist, but they will need to be tailored to accommodate the new organizational needs.

4.1 Marketplace Engagement

A key aspect of establishing a successful CPL Operation is to develop a thriving marketplace. The key to doing so is to build trust between the suppliers and the acquirers. Trust is built on open and honest communications. The primary ways in which the product line organization engages the marketplace is through the development of CPLSMs and sharing them with the marketplace via an RFI.

4.1.1 Development of CPLSMs

- Inputs: Requirements, needs statement(s)
- Outputs: CPLSMs

4.1.2 Communicating Government Needs to the Marketplace

- Inputs: CPLSMs
- Outputs: RFIs

4.2 Supplier Analysis and Qualification

Component product line suppliers may have different attributes from “traditional” component suppliers; however, the product line instances might be legitimately viewed as traditional components. The processes employed in the current organization for assessing suppliers and qualifying them to perform on a contract will likely need to be adjusted if the scope includes the product line aspects of the component.

Product line organizations are more likely to be commercial (as opposed to governmental) in nature and will make investments in the product line. These investments might take the form of improving performance, improving product life and upgradability, improving product quality, reducing cost or lead time, or supporting infrastructure.

4.3 Strategic Processes

4.3.1 Technology Surveying

An important part of component product line operations is assessing the marketplace for technology that might be employable for current or anticipated needs. An experienced product line contractor will likely already be conducting research on its product line components. In this context, there is some risk of the government pushing for specific new technology, as there may appear to be a potential conflict of interest if the new technology is acquired from a sole-source contractor. There may also be risk in suggesting potential areas of research as part of a technology survey if that technology is proprietary to a specific contractor.

In the context of new components, this risk is much lower. A contractor should be able to push its technology into a source selection and win the competition on its own merits.

4.3.2 Identification of Candidate Components

The process of creating CPLSMs, RFIs, and generally making the community aware that a new product line opportunity exists should include a means to review existing components for suitability with the new opportunity. These existing components may be viewed as COTS or GOTS (if a product might exist within the government).

One way to accomplish a 100% solution is to find a COTS component that does 80% and get the remaining 20% in a different way (e.g., modifying the COTS to do it all, creating a new component, or utilizing an existing component to make up the difference). In this way, a product development specialist might be able to provide the core functionality as part of its product line offering (the 80%). Regardless, an important aspect to the success of the product line organization is the ability to satisfy new technology needs with existing commercial offerings.

4.3.3 Alignment of Component Product Line Practice with Program Office Needs

For the CPL initiative to be successful, the enterprise needs to incentivize program offices to leverage the use of the product line components. Additionally, the product line organization needs to be responsive to its program office customers. The success of the CPL initiative will be based on the number of uses of the product line component specifications. Each time the product line component is not used represents a missed opportunity for the entire organization.

The enterprise will need to strike a balance between product line mentality and programmatic reality. Further, it will be extremely challenging to introduce and adopt the CPL practices within the program offices. Primarily, this is due to the culture that empowers program offices to do what it takes to get the project done and not rely on other organizations. Imagine that an integrator has a potential component for a system, but it is not the product line component that it has been directed by the program office to use (maybe the integrator's component has been built and demonstrated on another program but was lacking some relevant feature set that determined the product line component source selection). Let's also assume that the contractor providing the product line

component is having some difficulty with the development, and there is a risk of missing a delivery deadline. There may be pressure on the program office coming from the integrator to use its component.

What should the CPL initiative and the program office do? The CPL initiative could (1) reconsider its CPLSM and make an adjustment to allow the integrator's component to be compliant, (2) grant a waiver for this instance, or (3) maintain the existing course of action. The program office will need to manage this item as a risk, which will provide the necessary visibility to the other stakeholders, such as the enterprise. At some point, the organization will need to decide how to proceed.

This is just one example. There will be many other (less severe) ways to not follow the product line organization's guidance. The product line organization needs to work with the enterprise and the programs to instill the culture needed for successful product line implementation. Basically, it needs to build the trust in its own organization's competency to support program office needs while acting responsively to the enterprise.

4.4 Tactical Processes

In the following sections we suggest tactical governance processes. These processes center on managing the overall CPL activity. As such, they are the most likely to be tailored by each Product Line Champion.

4.4.1 Establishing, Maintaining and Prioritizing the Backlog

The backlog identifies planned work and provides the opportunity to communicate the plan to the other relevant stakeholders. Sub-processes should exist for (1) adding items to the backlog, (2) removing items from the backlog, and (3) establishing the priorities for the next increment of work. As work is being performed, the backlog provides a means to communicate status for the items that are on the list.

4.4.2 Component Product Line Configuration Control Board (CCB)

The CCB is one of the principal ways for new work to be identified and added to the backlog. Voting membership on the CCB is likely to be something that will need to be worked out among the stakeholder community. The CCB will need to establish a charter, and develop its specific product line sub-processes, to accommodate the needs of the stakeholders.

4.4.3 Justifying the CPL Effort

As the CPL Organization performs its work, there will be constant pressure from other stakeholders to limit its scope. The CPL Champion needs to accept this as the status quo, identify ways to measure the value of the CPL effort, and communicate this value to the stakeholder community. A natural opportunity to demonstrate value is to connect the product line's tasks with accomplishing the parent organization's broader goals, such as MOSA.

The CPL activities will most likely be funded through the parent organization, so the programs will want to know that their needs are being addressed. Additionally, the value to the parent organization (e.g., the Program Executive Office) comes from systematic reuse and proactive anticipation of component features and technology. Decisions made by the CPL Organization (regarding which components to prioritize, which features are common, and which provide variation, among others) will determine its ultimate success: These decisions will foster the trust of the WS program office and, ultimately, the value of the product line initiative to the parent organization.

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