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Design for Sustainment: Governance Engineering in Major Acquisition Programs

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Abstract

During acquisition for a sustainment-dominated, major capital asset, decision-making and action to develop the sustainment system must begin early in the acquisition process to sufficiently align the necessary integrated logistics support demanded by these systems. Effective governance improves the likelihood of success for delivery of the asset and accompanying sustainment system to ensure the asset meets expected performance and remains functional over its planned decades-long service life. The service life of a Navy vessel can range from 25 to 50 years. In this case study, we examine the operation of the governance system for major maritime acquisitions, wherein a fleet of multi-billion-dollar capital assets are acquired and sustained. In acquisition of sustainment-dominated systems, an effective governance structure is imperative for providing necessary policy, leadership, resources, and management. In a recursive organizational structure, each viable system contains, and must be contained within, a viable system. This theorem implies that integration and alignment at the next level of recursion is also needed, as well as influence when beneficial to maintaining viability of the total system. Sustainment systems for defense assets of similar financial caliber historically are troubled over their life cycle as programs compete with others to proactively plan for adequate product support. Organizations are challenged to invest in future sustainment, while limited resources are allocated to acquiring new capabilities and maintaining current capabilities (assets). All nine meta-functions described in the Complex System Governance Reference Model have been exercised in a new sustainment system and provide a framework for beneficially influencing program outcomes. This work-in-progress uncovers features of the CSG Reference Model as they continue to influence program decision and action over time. We report on the efforts to use agile development to develop a pilot sustainment system to provide integrated logistics support to the future fleet. This paper explores a model for necessary governance to develop and maintain governance as an organizational capability to sustain high-value capital assets.

Introduction

A sustainment-dominated system is characterized by having post-deployment life-cycle costs that exceed the original procurement costs. Thus, it is critical to plan for the operations and sustainment (O&S) phase of their life cycle early in acquisition, as sustainment may consume as much as 80% of total resources expended on the asset throughout its life cycle

(Sandborn, 2007). For defense systems with long life cycles, maintenance and modernization availabilities must support sustainment requirements and be completed within scheduled durations without deferring required maintenance to achieve required availability, enabling the return of assets to the fleet, avoiding idle time, and preventing unsustainable maintenance backlog growth (GAO, 2019; Sandborn, 2007). Life-cycle planning for operating and sustaining weapon system platforms considers expenditures for planned and corrective maintenance, downtime costs, lengthy and expensive qualification or certification cycles, configuration management, planning yard services, and others to keep the platform operational and mission-relevant.

Sustainment systems for defense assets with financial caliber of major ACAT I acquisitions are often historically troubled over their life cycle as programs compete with other priorities to proactively plan for adequate product support. There are also challenges for integration and alignment within the shared network of sustainment infrastructure, development of mutually compatible strategies to achieve disparate missions, and adapting to policy, or adapting policy for viability at a higher level of recursion. Lessons learned from successes in previous programs demonstrate the benefits of increased involvement in product support management throughout the asset life cycle, highlighting the need for more uniform and rigorous application of product support governance and best practices (Defense Acquisition University [DAU], 2019).

During acquisition for a sustainment-dominated, major capital asset, decision-making and action to develop the sustainment system must begin early in the acquisition process to sufficiently align the necessary integrated logistics support demanded by the asset. For acquisition of sustainment-dominated systems, effective governance provides necessary policy, leadership, resources, and management which improves the likelihood of success for delivery of the asset and accompanying sustainment system to ensure the asset meets expected performance and remains functional over its planned decades-long life cycle.

A useful starting point is a review of the external reporting by organizations such as the Government Accounting Office (GAO). These reports are relatively dispassionate analyses of problems encountered in significant government programs. The GAO found that the "Navy continues to face persistent and substantial maintenance delays that affect the majority of its maintenance efforts and hinder its attempts to restore readiness" (GAO, 2019, p. 2). The GAO noted that the causes of the delays spanned acquisition, operations, and maintenance itself, with the primary sources of problems in acquisition being optimistic sustainment assumptions, providing vessels to the fleet with defects, and failing to purchase technical data (GAO, 2019, p. 11). Other reports provide more depth on selected issues, such as when the GAO reported issues with technical data that had not been acquired during the acquisition phase (GAO, 2011). The GAO reported on the state of ship maintenance in 2017, drawing a connection between maintenance and four significant mishaps (GAO, 2017). Though the word *governance* is not used, the GAO highlighted the 14 recommendations made in an earlier report with the DoD "generally concurring in all of them," yet only one had been implemented at the time of the follow-up report. The pattern of these reports suggests a more effective governance system may provide beneficial effects.

Product Support Managers (PSMs) are entrusted by the DoD to fulfill Title 10 responsibilities, as well as "implementing and managing sustainment governance" (DAU, 2019, p. 59). While clearly effective governance is needed for sustainment-dominated systems, it is also a significant challenge. For a complex major acquisition program, a guiding governance framework beyond that of the *Product Support Manager (PSM) Guidebook* supports "proper application of standardized, comprehensive, and visible governance" (DAU, 2019, p. 59). This paper describes the applicability of the selected complex systems governance (CSG) framework and its potential to enhance the holistic development of a complex sustainment system. This case study–oriented paper examines the underlying governance of a Navy vessel's logistics program. In this paper, we provide (1) an overview of a sustainment-dominated systems and associated challenges encountered by the DoD; (2) discussion of the role of the PSM, outlining the Title 10 requirements that define the PSM scope of responsibility; (3) the Complex System Governance framework and methodology for application; and (4) discussion of the translation of the PSM responsibilities to a governance strategy tailored for a major acquisition program, leveraging the CSG framework to illustrate the guideposts that support sustainment governance for the program. We conclude with a discussion of the challenges ahead and considerations for future research.

Product Support Management Guidance for Defense Acquisition

Product Support Management is a life-cycle approach to deploying and maintaining the readiness and operational capability of major weapon systems, subsystems, and components (DAU, 2019). The need for Product Support Management was recognized through DoD concerns and realizations that 60–70% of system life-cycle costs were being incurred during Operations and Sustainment (O&S; DAU, 2019). The National Defense Authorization Act for Fiscal Year 2010 provided legislation (Pub. L. 111-84) containing a provision in Section 805 entitled "Life Cycle Management and Product Support" stating that the secretary of defense shall require that each major weapon system be supported by a PSM, with a set of responsibilities often referred to as "Title 10 Responsibilities."

Product Support spans the entirety of the product life cycle from requirements definition through to disposal and is comprised of 12 multidisciplinary Integrated Product Support (IPS) Elements (DAU, 2019, p. 3):

1. Product Support Management
2. Design Interface
3. Sustaining Engineering
4. Supply Support
5. Maintenance Planning & Management
6. Packaging, Handling, Storage, & Transportation (PHS&T)
7. Technical Data
8. Support Equipment
9. Training & Training Support
10. Manpower & Personnel
11. Facilities & Infrastructure
12. Computer Resources

The holistic scope of Product Support Management provides Program Managers with a tailored strategy for complex product design, deployment, and support. Program and Life-Cycle Managers rely on the PSM, established in 10 U.S. Code 2337, to develop and implement the comprehensive product support strategy (DAU, 2019). Communication, implementation, and execution of the product support (PS) strategy requires significant coordination with multiple internal and external service and supply agents. Therefore, the PSM employs Product Support Integrators (PSIs) to facilitate the product support strategy through formal arrangements (e.g., Memorandums of Understanding/Agreement, formal contracts, teaming agreements) with designated Product Support Providers (PSPs). The formal arrangements document mutual agreements for the scope of PS and resources provided and constrained in each individual arrangement.

A PS Strategy addresses life-cycle supportability in the context of operations and support environments. The strategy considers a balance of asset availability (operational and material) and planned downtime for maintenance events (dry dock availabilities, refits, and major overhaul and modernization events) while prescribing facilities, supply chains, training, and workforce capabilities. Logistics support analyses are iteratively completed throughout the life cycle to assess PS needs and inform the PS Strategy. As the platform matures, reliabilitycentered maintenance, maintenance task analysis, and level of repair analysis will inform provisioners and an evolving comprehensive maintenance concept.

Early PS efforts, particularly those undertaken prior to the transition from production to deployment, establish vital intermediate and depot maintenance capabilities. The *PSM Guidebook* recommends a viable organic depot maintenance capability be established within four years of the Initial Operating Capability milestone. In order to meet this aggressive timeline, integrated product/logistics support analysis must be carried out to inform the Life-Cycle Sustainment Plan (DAU, 2019). A dependency upon interim contract support agreements with original equipment manufacturers common in less-sensitive acquisitions is of particular concern to major asset sustainment where deployments can often exceed six months. Organic sustainment resources depend heavily upon the completion of support analyses to establish continuity between existing sustainment capabilities and those of future classes. The PSM is challenged with organizing resources, teaming arrangements, and alternatives analysis to ensure notional support activities will support the sustainment Key Performance Parameters (KPPs) and Key System Attributes (KSAs) defined in the Capabilities Development Document (CDD) and the Life-Cycle Sustainment Plan (LCSP).

The *PSM Guidebook* provides a framework for developing product support solutions through the appropriate blend of organic and commercial industry support to achieve cost-effective Warfighter operational readiness outcomes (DAU, 2019). While the *PSM Guidebook* frequently calls out “sustainment governance” and “product support governance” as “vital to fulfilling Warfighter A_M (Material Availability) requirements and achieving the Department’s program life-cycle management improvement objectives” (p. 59), it lacks operational definitions for both sustainment and governance. Sustainment is commonly referred to as a phase in the life cycle of the asset, although success in that phase requires sustainment to be an integral part of the program’s acquisition strategy and system design process.

Life-cycle sustainment involves decisions and actions from requirements definition early in design through the disposal of systems, which aim for the platform to be available at the right place, supported by appropriate resources, and in the right operational state as required by the customer, while minimizing the platform’s impact to its relevant stakeholders (e.g., cost, resource consumption, energy, etc.). Post-acquisition, system sustainment refers to “activities undertaken to (a) maintain the operation of an existing system (ensure that it can successfully complete its intended purpose), (b) continue to manufacture and field versions of the system that satisfy the original requirements, and (c) manufacture and field revised versions of the system that satisfy evolving requirements” (Sandborn & Lucyshyn, 2019, p. 2) via sustainment engineering processes.

For the purpose of this paper, governance is contextually defined as occurring within a “meta-system” responsible for design, execution, and evolution of those meta-system functions (“meta-functions”) necessary to provide communication, control, coordination, and integration for the complex system (Keating & Bradley, 2015). We supplement this description and offer that governance is a meta-activity in which the use of systems, structures of authority, and processes are executed to allocate resources and coordinate or control activity and development (Joslin & Müller, 2016; Müller, 2009; Pinto, 2014). For viability to be achieved, governance at an organizational level must coexist within the enterprise governance framework. We present a theoretically-derived model for governance with the underpinning of system viability as defined through sustainment metrics. Employing a suitable governance model organizes the flow of information, interdependent unit work, and critical stakeholder management required to achieve PS Strategy, LCSP goals, and CDD requirements.

The PSM challenges and tasking have been described in this section with sufficient detail to make clear the need for a full-bodied governance structure. The next section presents the Complex Systems Governance Framework as articulated in earlier work.

Complex System Governance Framework

Sandborn and Lucyshyn's (2019) definition of sustainment acknowledges the concept of "footprint" which represents the impact to the customer and relevant stakeholders. The concept of footprint is germane to the reality that the viability of a single program rests on the viability of an external organization's activities. The Law of Requisite Variety states that "systems of systems are recursively structured, such that each viable system contains and must be contained within a viable system" (Beer, 1979, p. 118), as depicted in Figure 1.

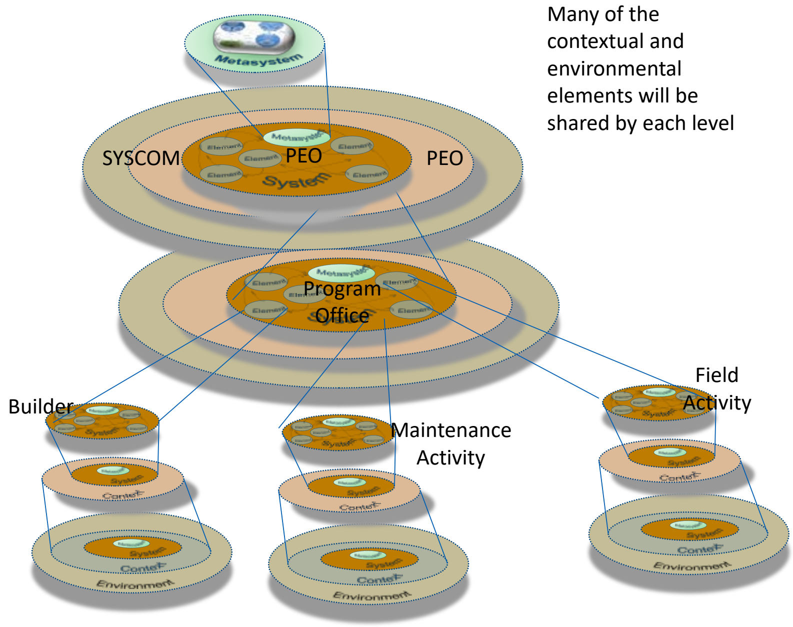

Figure 1. A Representation of the Recursion of Viable Systems

A contained system, as a viable system itself, can be thought of as a System 1 (S1) conducting primary activities to support the system in which it is contained. This theorem implies integration and alignment at the next level of recursion is also needed, as well as influence when beneficial to maintaining viability of the total system. Determination of which system is a recursion of another depends on the vantage point for analysis and perspective of the interpreter, which determine the boundaries as appropriate given a specific inquiry. As an example, organic intermediate and depot maintenance facilities provide resources and services to maintain ships and submarines, as well as help develop the maintenance products that they ultimately use once newly acquired assets enter the fleet. From a different perspective, the maintainer is one of multiple "customers" to which acquisition programs must provide deliverables (e.g., logistics support requirements).

The Complex System Governance Reference Model, an evolution of Stafford Beer's Viable System Model, offers a set of nine interrelated meta-functions described in Table 1.

Table 1: Governance Meta-Function Descriptions (Keating & Bradley, 2015)

Meta-function	Description
Policy & Identity (M5)	Provides direction, oversight, accountability, and evolution of the System. Focus includes policy, mission, vision, strategic direction, performance, and accountability for the System such that: (1) the System maintains viability, (2) identity is preserved, and (3) the System is effectively projected both internally and externally.
Strategic Monitoring (M5')	Monitors measures for strategic system performance and identifies variance requiring metasystem-level response. Particular emphasis is on variability that may impact future system viability.
System Context (M5*)	Maintains the system context (the circumstances, factors, conditions, or patterns that enable and constrain the system) to inform strategic direction.
System Development (M4)	Provides for the analysis and interpretation of the implications and potential impacts of trends, patterns, and precipitating events in the environment. Develops future scenarios, design alternatives, and future focused planning to position the System for future viability.
Environmental Scanning (M4')	Monitors environmental trends for informed response and adaptation to support adjustment of strategies and initiatives to compensate for system needs and environmental shifts.
Learning & Transformation (M4*)	Provides for identification and analysis of metasystem design errors (second order learning) and suggests design modifications and transformation planning for the System.
Systems Operations Management (M3)	Primary function is to maintain operational performance control through the implementation of policy, resource allocation, and design for accountability.
Operations Performance (M3*)	Performance monitoring mechanisms to effectively monitor and improve performance.
Information & Communication (M2)	Design, development, implementation, and support of channels for coordination and the flow of information to support effective communication and coordination.

These meta-functions and their interrelations each play a role in the development of the new sustainment system and provide a framework for beneficially influencing program outcomes. A depiction of the most significant relationship flows is presented in Figure 2. The flows assist in determining “where to go next” when exercising the model, as described later.

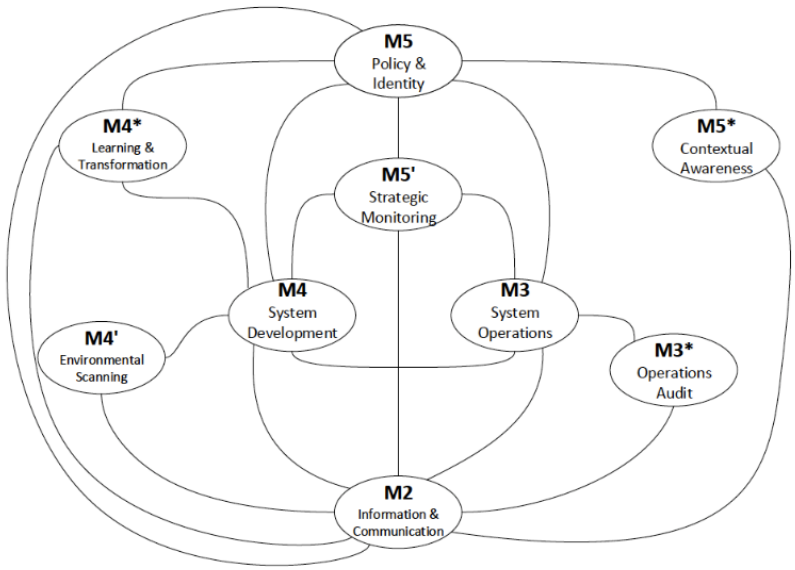

Figure 2. Governance Meta-Function Descriptions

Action Research: Implementing and Expanding Complex Systems Governance

The complex systems governance framework provides a reference point to the natural inquiries of governance, with a common set of “meta-functions” as explanatory references for the derivative behaviors, activities, actions, and tasks that follow, regardless of an agent’s cognizance of the existence of a governance meta-function as they are articulated in the CSG framework. Through its application in a truly complex acquisition program environment, action research supports expansion and improvement of the theoretical understanding for future applications.

Action research is both a theoretical and practical approach which aims to provide practical values in subject organization cases while also acquiring new theoretical knowledge in an actionable and iterative way by actively participating in dialogue and providing feedback to the participating organizations while observing and analyzing effects when decisions and actions are made and drawing upon theory. By engaging in action research, the available knowledge about CSG is expanded.

The action research methodology involves iterating through five identifiable processes: “diagnosis, action planning, action taking, evaluation and specifying learning” (Susman & Evered, 1978). Diagnosis involves making theoretical assumptions about the nature of the organization and its problem domain and can be done using a variety of methods, such as observation, document reviews, and interviews, to the extent that organization representatives are able to help researchers better understand the organizational context and problem domain. The action plan is developed to define the target for change and the approach by which change is pursued, including actions to support the change from the current to desired state, a selected measure for evaluating the suggested actions and their influence on meeting organizational goals, as well as changes to meet those goals.

Notably, action research introduces several interesting characteristics also pertinent to considerations for governance:

- Action research by its very nature is agile—initial understanding informs a concept of what might work. Trying that idea out and then evaluating its success or failure informs learning. This new learning is used to modify the idea, and another round of doing follows (Dick, 2018).

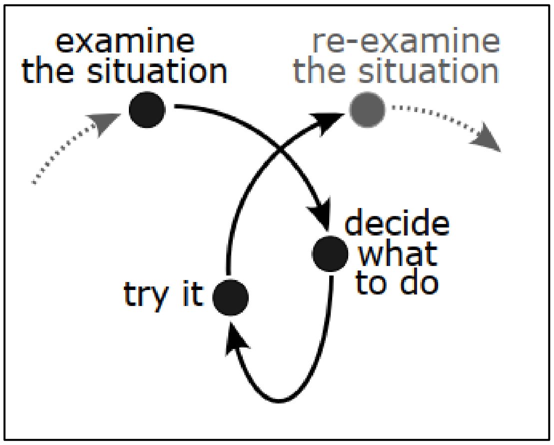

Figure 3. Action Research Loops (reprinted with permission from R. Dick)

- Action research is not value-free, but rather embeds and exposes the values of the participants. When the exposed values do not comport with the espoused values of the organization, leaders must act, or everything slows or stops.
- One cannot work out all the consequences of an action beforehand. In action research, “not only is knowledge gained by acting in the real situation, but the situation is itself simultaneously product of the current level of knowledge” (Susman & Evered, 1978, p. 599).

Following the presentation of results, evaluation leads to collaborative specification of learning goals, conducted as an ongoing process to acquire new knowledge and integrate it into what is currently known and defined in the Complex Systems Governance framework. With this foundation guided by action research, we now look at the PSM’s role, responsibilities, and approach to building a sustainment system.

Discussion: Product Support Manager’s Role in Complex System Governance

The complex system governance framework provides an organized way of understanding how systems of systems must work together with what is and is not under direct control and maintain a model of the product support needs for the asset. A solid governance strategy supports the vision and guidance necessary for involving appropriate stakeholders and resources (internal and external), as product support cannot be developed in a vacuum. In doing so, the PSM aims to provide an acceptable, holistic solution for stakeholders involved such that their own viability is not challenged by the asset and/or its sustainment system.

Table 2 maps the mandated PSM responsibilities for a major weapon system to the corresponding CSG framework metasystem function responsibilities.

Table 2: Comparison of *PSM Guidebook* Governance to CSG Reference Model

Product Support Manager Responsibilities	CSG Meta-function	Corresponding Complex System Governance Practitioner Responsibilities
(A) develop and implement a comprehensive product support strategy for the weapon system.	M5	• Policy & strategic direction • Disseminates strategic plan and oversees execution
(B) use appropriate predictive analysis and modeling tools that can improve material availability and reliability, increase operational availability rates, and reduce operation and sustainment costs.	M4	• Predictive analysis implies its use for future system development
	M3*	• Initial status monitored by M3* and current data feeds modeling to identify the "as is" and "to be" system
(C) conduct appropriate cost analyses to validate the product support strategy, including cost-benefit analyses as outlined in Office of Management and Budget Circular A–94.	M4	• Guiding investment priority, and looks to support mission/vision
	M3*	• Assess cost performance to validate product support strategy
(D) ensure achievement of desired product support outcomes through development and implementation of appropriate product support arrangements.	M5	• Defining and integrating expanded network for system (strategic partnerships) • Establishes system policy direction and maintains identity of the system—executed through strategic direction. • Provides for capital resources necessary to support system • Sets present and future problem space for focus of product, service, and content development and deployment • Disseminates strategic plan and oversees execution • Arrangements->measuring success of defined relationships between elements
(E) adjust performance requirements and resource allocations across product support integrators and product support providers as necessary to optimize implementation of the product support strategy.	M5'	• Recommendations for continuance, modification, or deletion of performance measures
	M3	• Resource planning for operational requirements • Establishes operational goals in relationship to strategic performance objectives • Sets priorities and resource allocation for operational support activities and investments • Determines performance measure targets
(F) periodically review product support arrangements between the product support integrators and product support providers to ensure the arrangements are consistent with the overall product support strategy.	M5'	• Dashboard measures for strategic system performance • Results of inquiry and analysis of performance issues • Conducts inquiry into performance aberrations • Informs development of the strategic plan

Product Support Manager Responsibilities	CSG Meta-function	Corresponding Complex System Governance Practitioner Responsibilities
(G) prior to each change in the product support strategy or every five years, whichever occurs first, revalidate any business-case analysis performed in support of the product support strategy.	M5’	• Track ongoing performance of system based on dashboard measures of performance for operations • Track ongoing performance of product support strategy and resulting sustainment system based on dashboard measures of outcomes or forecasted outcomes/realization of strategic goals • Monitors and assesses the continuing adequacy of operational performance measures • Informs development of the strategic plan
	M5*	• Monitor and assess the influence of contextual aspects for the system • Recommend adjustments to strategy direction based on the context we are monitoring
	M5	• Evolve scenarios for system transformation and implement strategic transformation direction
(H) ensure that the product support strategy maximizes small business participation at the appropriate tiers.	M4’	• Design for environmental scanning for the entire system (includes trends, changes, patterns, critical stakeholders, collaborative entities, research, etc.) • Execute the environmental scanning designs • Capture emergent environmental conditions, events, which lead to system development
	M4	• Identify future relationships critical to system development • Identify future development opportunities and targets that can be pursued in support of mission and vision of the system
	M5*	• Context & Stakeholder Analysis
(I) ensure that product support arrangements for the weapon system ***describe how*** such arrangements will ensure efficient procurement, management, and allocation of government-owned parts inventories in order to prevent unnecessary procurements of such parts.	M4	• Guides investment priorities
	M5	• Define, clarify and propagate the system vision, strategic direction, purpose, mission, and interpretation. • Establishes system policy direction and maintains identity of the system—executed through strategic direction

At first glance, the team recognized a lack of emphasis on recognition for the vast stakeholder base and identification of a clear line of authority. Our assessment is that the *PSM Guidebook* is most heavily oriented to Policy and Identity (M5), with shortfalls in conveying the complexity of developing the future model of the system (M4). Other observations included the absence of Learning and Transformation (M4*) and lack of explicit guidance for Communication and Information (M2).

The current organizational structures for building and maintaining a class of ships or submarines is divided among numerous different commands and flag officers, with their respective staffs, who report through different reporting seniors. Many of these have competing priorities and are not incentivized to focus on sustainment of a single class. The opportunities for organizational cross-threading are obvious.

In many acquisition programs, there are organizations that have equal or more control over the product support outcomes than the PSM. Sustainment planning complexity is amplified by the lack of a centralized PS command and control structure. There is no single authority or reporting structure: outcomes of product support strategies are influenced by multiple autonomous entities, their policies, and decisions. The PSM does not determine the entire platform's product support strategy, as it precludes some systems under the cognizance of entities to other acquisition program offices, which can have their own technical and logistics support/sustainment authority. Despite the PSM possessing authority over sustainment planning and execution, in many scenarios, they do not reside in the chain of command for PS Integrators and Providers and depend upon other acquisition entities for funding and task prioritization. It is critical to identify common goals, set boundaries of responsibility, and communicate expectations with external entities which invoke policy and development that influence outcomes. Without cooperation, decisions may be made that conflict with the trajectory for desired outcomes and compromise future program success.

The *PSM Guidebook* defines what must be done, although it does not convey the true burden of PS Business Model execution. DoD guidance expects total lifecycle systems management from the enacted support strategy, yet once the asset is in service, the PSM does not control many of the resources necessary to sustain the asset; instead, the PSM must "ensure achievement of desired product support outcomes through development and implementation of appropriate *product support arrangements*" (1D). Because arrangements are made with predictions of the future circumstances which may change, the PS Strategy must connect with the needs of the weapons system platform. Iterative validation of plans and analyses, including the LCSP, logistics support analyses, and resource allocations, depend upon high levels of coordination as issues such as equipment obsolescence, maintenance and modernization funding, and skilled workforce attrition increase with platform age.

The PSM must establish a PS Strategy within the constraints of external stakeholders and their competing priorities and objectives by deciding early to work closely with entities that may influence program outcomes and control resource decisions. By doing so, the PSM may reduce the probability of tension arising from future misalignment which may limit and adversely impact the PS Strategy. The PSM has greatest flexibility in defining a PS Strategy at Milestone A (DAU, 2019). This flexibility progressively declines through each phase of the life cycle as more decisions are made regarding the design, construction, and sustainment of the asset in service. In recognizing that, how do you set up a sustainment system, a way of managing your program, when others are interested in protecting the proverbial rice bowls—20 years before the asset shows up? *By establishing the relationships necessary to develop win-win solutions and deliver a viable sustainment system.* To quote the Honorable James "Hondo" Geurts (Assistant Secretary of the Navy for Research, Development, and Acquisition), "take the time to build relationships before you need a relationship" (Ryan, 2020).

Policy Invokes Requirements for Governance

At the DoD level of recursion, the Joint Staff establishes a set of sustainment metrics to guide performance monitoring throughout the program life cycle, the Key Performance Parameter (KPP) being Availability (comprised of material and operational availability), and two Key System Attributes (KSAs), Reliability and O&S costs. These requirements are established early in the material solution analysis to explicitly define materiel readiness goals for the asset through its life cycle. From a governance perspective, they also provide a framework to align the vision for the sustainment system. The Policy and Identity meta-function is evident by fulfilling responsibilities such as

- Exercising strategic dialog forums and mechanisms for defining and clarifying the identity of the sustainment system, its purpose, vision, and mission, the strategic direction, and interpretation of present and future focus.
- Participating in forums to represent the sustainment system interests to external constituents and establishing strategic partnerships in the expanded network of the sustainment system. Reporting on the results of the PSM's efforts in executing the PM-approved sustainment strategy is intended to strengthen sustainment governance by providing visibility of factors key to sustainment and success of that strategy to senior management.
- Establishing and maintaining the sustainment system identity through policy to balance autonomy and integration within the system in the face of changing environment and context.
- Evolution of scenarios for sustainment system transformation and steering the direction for achieving strategic transformation.

From early in its existence, program offices should recognize that the exceptional longevity of platforms and associated systems, as well as the stringent operational requirements, require a sustainment system to match the variety imposed by the challenging logistics environment. The Design-Build-Sustain emphasis should include early sustainment-driven design choices for systems and arrangements promoting enhanced sustainment through the class life cycle, as well as highlight the need for parallel development and enhancement of their planned logistics support infrastructure to meet the needs of the future fleet. As the design matures and Initial Operation Capability date transitions from an amorphous date to a more visible goal line, a vision of “Ready for Maintenance” clearly focuses the team members on the tasks needed to support that critical first maintenance period with the maintenance activity truly ready with all the supporting elements and cast to hit the maintenance period running.

Sustainment System Development

The System Development (M4) meta-function refers to the activities which develop the model of the current system and a clear vision of the future sustainment system with a visible map of how it will produce future value through the O&S phase. The overall goal of System Development is for the PSM to influence strategic product support development plans that are adaptive to changing context, performance goals, and policy. Development of the sustainment system involves extensive analyses and interpretations of the implications and potential impacts of trends, patterns, and precipitating events in the environment. Governance involves the development of future scenarios, design alternatives, and future-focused planning to position the system for future viability.

Both Environmental Scanning (M4’) and Learning and Transformation (M4*) meta-functions support the continual development of the Sustainment System (M4). Exercising this meta-function involves monitoring internal and external gaps in product support and sustainment system adequacy and designs for entire systems’ environmental scanning, including trends. It maintains a “model” of the program environment, captures emergent environmental conditions and events, and allows for synthesis of the meaning, which is then disseminated environmental information throughout the system. It also includes decisions related to maintaining configuration of product data models across the life cycle. As meta-functions are interrelated, contextual elements of the enterprise and its strategic direction (M5* and M5’) are key inputs to M4, particularly as the PSM aligns development efforts for the sustainment system to other organizational initiatives for modern logistics information and technology systems.

Learning and Transformation (M4*) through Design for Sustainment

The Learning and Transformation (M4*) meta-function, although not emphasized in the Title 10 responsibilities, is a critical element for governance. Learning facilitates the evolution of product support, but also involves transformation of the DoD components if their business processes do not satisfy program requirements, or if their way of doing business comes at the cost of viability of another organization or a set of organizations (M4*). Governance through M4* implies continual adaptation and design of underlying system and business processes through fundamental double-order learning to improve future execution.

Agility entails choosing a viable path for value and incrementally building towards a full solution while rapidly adapting the approach as necessary to continually improve processes and the ability to reach the goal. The PSM can promote agility within the integrated product support team's culture by emphasizing the insufficient time available to develop a perfect logistics supportability analysis process before beginning the process. In a high-stakes capital acquisition program, the process must evolve while executing, or opportunities to influence product quality outcomes can be missed throughout the delivery of technical data for thousands of configuration items. As the maturity of the asset evolves from concept to design to engineering to production, the team must adjust their involvement and focus on asset maintainability and supportability. In doing so, an agile process prescribes regular review of outcomes as opportunities to adjust for learning between execution intervals. As an example, the *PSM Guidebook* refers to validation of data collection channels to identify potential maintenance strategy adjustments. CBM+ initiatives are leveraged to develop PS Strategies (Baker, Nixon, Banks, Reichard, & Castelle, 2019; Banks et al., 2014). This approach will support operational availability throughout the asset's life cycle by triangulating data for diagnostic and prognostic applications when determining maintenance strategies, thereby reducing the learning curve.

Early in acquisition, there is more flexibility in experimenting with new business processes and exploring new standards to obtain necessary buy-in and allow for learning before becoming a Program of Record. The Learning and Transformation meta-function (M4*) refers to the intentional focus on identification and correction of sustainment system design errors implying incompatibility to a mission-meeting asset. Critical conversations surrounding regular internal assessment are necessary to enable broad and rapid learning. For learning and transformation to take place, cooperation is needed to balance autonomy and integration via governance. In exercising M4*, program "pilots" provide opportunities to challenge existing organizational structure.

Scanning the Environment (M4') for Potential Impacts to the Program

Lessons learned from previous programs can help inform managers of new programs; many impacts of previous decisions on existing sustainment system designs for existing programs are relevant due to commonality in "pull-through" systems, as well as commonality in shared maintenance infrastructure. In the CSG framework, the Environmental Scanning meta-function refers to activities which lead to detection of environmental factors, trends, patterns, and themes to inform response, strategic adaptation, and initiatives by identifying gaps that challenge viability, and provide evidence for the need to compensate for sustainment system needs and environmental shifts.

Principle PSM duty #4 is to "seek to leverage enterprise opportunities across programs and DoD Components. *Enterprise strategies are a priority where the component, subsystem, or system being supported is used by more than one Component.* Product support strategies should address a program's product support *interrelationship with other programs* in their respective portfolio and *joint infrastructure*, similar to what is performed for operational interdependencies" (DAU, 2019, p. 9). In-service assets provide a wealth of signals about the underlying sustainment system health, particularly when the future asset shares a number of systems common to previous classes. This can be evaluated by leveraging relationships with agencies collecting and analyzing work stoppage data (inability to conduct work successfully, including due to cannibalization or materiel diversion) on common systems at risk for degrading platform Operational Availability. This can trigger logistics supportability analyses to identify recommendations for greater flexibility and success in component levels of repair. Failure Reporting, Analysis, and Corrective Action Systems (FRACAS) can provide management visibility and control for reliability and maintainability, facilitate improvements to hardware and associated software through timely and disciplined utilization of failure and maintenance data, and lead to implementation of effective corrective actions to improve failure rates and reduce maintenance burden. An ideal FRACAS program supports reliability improvement throughout the life cycle, from initial product design/redesign to identify and eliminate known issues to product support in the field through a closed-loop problem resolution process. The FRACAS process itself requires system governance as it involves various functional groups, each controlling a segment of each case, challenging broad participation, efficient workflows, and effective interactions.

The M4' meta-function is responsible for the planning and execution of the scheme for environmental scanning and dissemination of essential information (i.e., events, patterns, trends, opportunities, threats) to inform development of the strategic plan. Using a gap analysis process, current facilities must be assessed, future needs articulated, and gaps identified. Those gaps which require military construction (MILCON) efforts are identified and turned into projects. Working with key field-level stakeholders, the prospect of ready facilities for the new class is now achievable. Planned facility projects are visible elements of the system strategic plan, which are a product of M4. The development of MILCON plans via gap analysis is a key part of preparing the future sustainment system infrastructure, which is being developed in parallel to the platform. Lessons learned demonstrate that the facility infrastructure shortfalls need to be addressed long before they are needed. The coordination required between acquisition programs and facility providers is not well defined or understood.

Formation and Management of Sustainment System Operations (M3)

The System Operations meta-function (M3) refers to the collection of activities that provide oversight for products, services, value, and content delivery. As is the case with other meta-functions within the framework, M3 applies to where the boundary of the system lies, from the captured perspective: At what level of recursion and what perspective are we considering?

The System Operations meta-function (M3), as an integral component of management functions, establishes specific goals, allocates the resources necessary for development activities, and executes the operating agreement with the team assembled for an effort to design, implement, and execute the sustainment activities. The team providing M3 is an element of another system, and from that perspective, a System 1 (S1) within the host of other S1s that create the substantive products and contribute to the sustainment system at a different level of recursion. An example of how this is done is through derivation of sustainment funding requirements, which involves a host of stakeholders responsible for contributing to the development of the Sustainment Program Baseline. As articulated by the 2019 Section 809 Panel, Recommendation 42 is to create a funding type to support the Sustainment Program Baseline (SPB) and "reduce budgetary uncertainty, increase funding flexibility, and enhance the ability to effectively execute sustainment plans and address emergent sustainment requirements" (Section 809 Panel, 2019). Initiatives like Better Buying Power 2.0 and the Navy Readiness at Cost Model address the concepts of Will Cost (estimates based on a "historically informed independent cost estimate used to baseline program budgets") and Should Cost (estimates derived through "continuous analysis of cost drivers and initiatives to reduce the impact of those cost drivers without degrading effectiveness or suitability;" O&S Cost Estimating Guide, 2016, p. 12). A program's Will Cost Estimate is developed with input from multiple sources, including but not limited to a Manpower Estimate Report (MER), Class Maintenance Plan (CMP), maintenance and industrial facility upgrades, etcetera, and *each owned by a different entity.*

Operational Performance Audit (M3*)

The PSM exercising M3 recognizes the role of resource bargaining at play, as the program is an S1 when looking "up" to the next level of recursion across the organization at large. Looking "down," a potential trade-space also exists for the resource allocation to aspects of the sustainment system. To fully realize the cost opportunities of the trade space and determine the appropriate blend of organic and industry support, governance is needed for the design and implement accountability and business rules, standards, and processes. While M3 is concerned with all aspects of resource planning for operational requirements, determining performance measure targets, and setting priorities for resource allocation to support activities, peripheral meta-function for operational performance audit (M3*) executes the design for accountability of operational support activities as an outcome of establishing appropriate mechanisms for monitoring the development of necessary product support. The M3* meta-function can be exercised at multiple levels by multiple roles. An example of M3* exercised at a working level is the oversight for logistics products and services and the value of technical data delivered by the shipbuilder to support the warfighter and maintainer. Another example, at the PSM level, is the design for evaluating supporting command performance with respect to the funding allocated to support program objectives.

Communication and Information Governance

Communication and Information (M2) is at the heart of the CSG framework. It enables all other meta-functions and their channels, as well as the regular updating of the governance strategy through adoption of agile principles. In the current list of PSM responsibilities, communication and information governance (M2) is downplayed, yet it is a critical component for fulfilling the role. Success as a PSM relies on the ability to communicate a vision and solicit buy-in for product support decisions, as well as the need to decisively escalate issues requiring attention from senior leadership and clearly articulate program impacts. It also relies on the ability to organize the communication structure within the design of the sustainment system. Conway's (1968) Law states that "organizations which design systems ... are constrained to produce designs which are copies of the communication structures of those organizations" (Conway, 1968). By this law, when there exists a set of possible system designs that can meet a requirement, the choice of the participants involved in the design will influence the process of selecting the design from a broad set of (potentially superior) alternatives. Applying this logic, "stove-piped" organizations and programs are a product of their constrained communication and information channels, which generate solutions limited by their interactions. Applying this logic to defense system acquisition, a design effort for a sustainment system should be organized according to the need for communication among diverse stakeholder groups, or else risk producing a product support strategy limited by the producing organization or participating organizations.

Human communication is enhanced by the contextual landscape of the program, which may be influenced by program governance. As an example, the DoD mandatory policy for integrated product teams (IPTs; DoD 5000.2) describes the vision for cross-functional team relationships within an organizational structure to expedite and enhance decision-making quality. Success requires that doing so is a human element, not a contract element: contracts put people near each other but do not necessarily build effective teams, which are developed through leadership. Awareness of governance and its effectiveness is evident through interactions which enhance visibility of what is working and what is not. Gaps in desired effects prompt the PSM to make necessary adjustments in how the teams will work together and if necessary, modify product support arrangements. The government–shipbuilder relationship benefits from this structure by seeking mutually beneficial stakeholder involvement, setting expectations for communications, increasing cohesiveness of team-building, and accelerating desired norms. A successful Sustainment Program must be established early in the acquisition process. It should include the contractor, the program office and maintainers who are actively involved in every phase of development for design arrangements and continue to be involved in the planning and analyses for logistics support.

Communication and information governance (M2) also supports delivery of valuable information for the warfighter and maintainer through acquired engineering and logistics data that defines the platform's design and will be used to plan and execute maintenance for decades into the future. As the organization upgrades maintenance facilities, the IT infrastructure will also need to be upgraded to address gaps in capabilities for consuming modern file formats for maintenance, repair, and additive manufacturing activities over the life cycle. A key governance responsibility for M2 is to design the information architecture and establish standard processes and procedures for information transduction. Establishing necessary data governance in alignment with the DoD Digital Engineering Strategy will involve considerations for how product model data will be used and managed by a broad user group to meet product support requirements and optimize readiness and affordability through integrated, model-based approaches and centralized product life-cycle management.

Overcoming Challenges

A number of challenges are known and require action. These include governance metrics, a lack of an interconnected Logistic Support Analysis Record (LSAR) with configuration control and accessibility for diverse stakeholder groups, and a divergence of the mental model of system participants with respect to perceived complexity and program priorities.

Implementing and scaling truly agile processes heavily weighs on the ability to promote agile practices: cross-functional teams (e.g., IPTs, cross-disciplinary, etc.), incremental and iterative delivery of products, prioritization, transparency, coordination, collaboration, and feedback. For geographically dispersed teams, collaboration and workflow tools compatible with enterprise infrastructure and requirements could enhance program potential via enhanced productivity and the ability to implement agile practices.

The *PSM Guidebook* requires the PSM to develop, maintain, and use metrics, and refers the PSM to the draft JCSA Handbook (DAU, 2019, p. 101). The metrics provided as samples are typical management metrics (e.g., "% Authorizations Error Free," but do not address recognized governance metrics which would measure governance directly). This is not unexpected, as most governance approaches with measures are oriented to corporate financial performance and incentivize according to the behavior they hope to drive. Future research on a metrics framework for measuring CSG performance is a potential future research avenue.

Discussions with stakeholders and program participants reveal different mental models about the problem at hand. Anthropologists suggest sense-making, the ability to make sense of an ambiguous situation and update one's mental model, as a key element of any effort to tackle complex systems. A handy starting point is the Cynefin framework as a guide to enable sense-making. While several efforts have been made in this area, a full exploration of the mental models and how to accommodate the differences remains future research.

Conclusions and Future Research

The basic operations of the complex system governance model within an actual organization have been described. The framework allowed better decision-making and conscious choices based on a system-level understanding rather than a siloed, disjointed approach. Our work is ongoing, with new insights gained frequently. The flexibility of the model has allowed adaptation to a very complex problem.

The governance framework for sustainment over an asset's life cycle will evolve to incorporate required elements and become the underlying basis for the mission, functions, and tasking of the future in-service program office. The inherent governance influences the program culture during acquisition and provides the foundation for fulfilling future responsibilities. It supports building mental models, sense-making, and focus on who can approve, who makes decisions, and who funds solutions. This ensures the appropriate level of support and flags when help is needed. The in-service program office will provide the organizational structure to execute the product support strategies and monitor their effectiveness at and compatibility with meeting fleet and maintainer needs.

The increasing emphasis on sustainment during defense system acquisition warrants future research on governance to benefit government agencies by providing guidance and solutions for IPT communication strategies, policy for resilient contract structure, data governance, and business process re-engineering.

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