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Department of Defense Field Activities as Enablers of the Defense Industrial Base for the Acquisition of Surface Navy Combat Systems

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Preface & Acknowledgements

During his internship with the Graduate School of Business & Public Policy in June 2010, U.S. Air Force Academy Cadet Chase Lane surveyed the activities of the Naval Postgraduate School's Acquisition Research Program in its first seven years. The sheer volume of research products—almost 600 published papers (e.g., technical reports, journal articles, theses)—indicates the extent to which the depth and breadth of acquisition research has increased during these years. Over 300 authors contributed to these works, which means that the pool of those who have had significant intellectual engagement with acquisition issues has increased substantially. The broad range of research topics includes acquisition reform, defense industry, fielding, contracting, interoperability, organizational behavior, risk management, cost estimating, and many others. Approaches range from conceptual and exploratory studies to develop propositions about various aspects of acquisition, to applied and statistical analyses to test specific hypotheses. Methodologies include case studies, modeling, surveys, and experiments. On the whole, such findings make us both grateful for the ARP's progress to date, and hopeful that this progress in research will lead to substantive improvements in the DoD's acquisition outcomes.

As pragmatists, we of course recognize that such change can only occur to the extent that the potential knowledge wrapped up in these products is put to use and tested to determine its value. We take seriously the pernicious effects of the so-called "theory–practice" gap, which would separate the acquisition scholar from the acquisition practitioner, and relegate the scholar's work to mere academic "shelfware." Some design features of our program that we believe help avoid these effects include the following: connecting researchers with practitioners on specific projects; requiring researchers to brief sponsors on project findings as a condition of funding award; "pushing" potentially high-impact research reports (e.g., via overnight shipping) to selected practitioners and policy-makers; and most notably, sponsoring this symposium, which we craft intentionally as an opportunity for fruitful, lasting connections between scholars and practitioners.

A former Defense Acquisition Executive, responding to a comment that academic research was not generally useful in acquisition practice, opined, "That's not their [the academics'] problem—it's ours [the practitioners']. They can only perform research; it's up to us to use it." While we certainly agree with this sentiment, we also recognize that any research, however theoretical, must point to some termination in action; academics have a responsibility to make their work intelligible to practitioners. Thus we continue to seek projects that both comport with solid standards of scholarship, and address relevant acquisition issues. These years of experience have shown us the difficulty in attempting to balance these two objectives, but we are convinced that the attempt is absolutely essential if any real improvement is to be realized.

We gratefully acknowledge the ongoing support and leadership of our sponsors, whose foresight and vision have assured the continuing success of the Acquisition Research Program:

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James B. Greene, Jr.
Rear Admiral, U.S. Navy (Ret.)

Keith F. Snider, PhD
Associate Professor

Panel 12 – DoD Field Activities as Enablers of the Defense Industrial Base: A Navy Example

Wednesday, May 11, 2011	
3:30 p.m. – 5:00 p.m.	**Chair: Dohn Burnett,** Head, Warfare Systems Department, Naval Surface Warfare Center Dahlgren Division ***Department of Defense Field Activities as Enablers of the Defense Industrial Base for the Acquisition of Surface Navy Combat Systems*** H. Glenn Woodard, Warren Lewis, Gilbert Goddin, and Wendy Schaeffer, Naval Surface Warfare Center Dahlgren Division ***Department of Defense Field Activity Roles as Enablers for the Industrial Base: Naval Laboratory Analysis that Supports Key Acquisition Decisions*** Steve Sovine, Lorilee Geisweidt, Nathan Miller, and Dave Clawson, Naval Surface Warfare Center Dahlgren Division ***In-Service Support of Surface Navy Combat Systems: Safety, Effectiveness, and Affordability Reviews: The Systems Engineering Process at NSWC PHD*** CDR Stephen Meade, Kris Hatakeyama, Juan Camacho, Karen Brower, and Dave Scheid, USN, Naval Surface Warfare Center Port Hueneme Division

Department of Defense Field Activities as Enablers of the Defense Industrial Base for the Acquisition of Surface Navy Combat Systems

H. Glenn Woodard—Systems Engineer, Naval Surface Warfare Center, Dahlgren Division (NSWCDD). Mr. Woodard earned his BS degree in mechanical engineering from Old Dominion University in 1988. Over the past 20 years, he has performed as an Aegis systems engineer, conducted system and element level requirements analysis, test and evaluation, and data analysis. Mr. Woodard is currently the program director for ACB Planning.

Warren Lewis—Strategic Insight, Ltd., serves the Senior Warfare Analyst in the NSWCDD Warfare Systems Department Systems Engineering War Room Complex. A 1979 graduate of the U.S. Naval Academy, Mr. Lewis has an extensive at-sea naval operations, strategic planning, training, and weapons system Fleet introduction background. He has 25+ years of operational and technical experience working to develop and implement surface warfare policies and programs.

Gilbert Goddin—Systems Engineer, Naval Surface Warfare Center, Dahlgren Division (NSWCDD). Mr. Goddin earned his BS degree in electrical engineering from Old Dominion University in 1986. Over the past 20 years, he has performed combat systems engineering and analysis related to the Aegis Combat System, ballistic missile defense, the USS *George H. W. Bush* (CVN 77) and *PCU Gerald R. Ford* (CVN 78) warfare systems, the DDG 1000 mission system, and product line systems engineering. Mr. Goddin is currently the Chief Engineer for the Warfare Systems Department at NSWCDD.

Wendy Schaeffer—Systems Engineer, Naval Surface Warfare Center, Dahlgren Division (NSWCDD). Ms. Schaeffer earned her BS degree in mechanical engineering from University of South Carolina in 1992 and her MSE degree in systems engineering from Virginia Polytechnic Institute in 1996. Over the past 20 years, she has performed systems engineering analysis related to warhead and missile design and more recently, combat systems requirements analysis.

Abstract

A key role of Department of Defense (DoD) Field Activities is to ensure the United States government is a smart buyer for its systems by translating the warfighter's operational requirements into engineering requirements and then providing product definition and development process oversight. As the Navy transitions away from building large end-to-end, platform-unique systems toward cross-platform capabilities, the role of systems engineering working horizontally across surface ship Programs of Record (POR) has become increasingly critical. DoD Field Activities continue to focus primarily on the definition and design of capabilities needed to close warfighting gaps but with an increased emphasis on the identification of areas of commonality. Done properly, these cross-POR systems engineering efforts will increase commonality across platforms and increase the potential for competition for combat system components. Combined with a new acquisition approach, these increased competitive opportunities for a wider range of industry partners will result in reduced costs associated with providing combat systems that effectively and efficiently meet the warfighter's needs.

The Surface Navy is using an Advanced Capability Build (ACB) combat system modernization approach to implement warfighting requirements across platforms. DoD Field Activities scientists and engineers provide technical leadership for systems engineering that will effectively focus industry efforts. This includes developing long-range plans for combat system upgrades, developing and maintaining combat system-level requirements and architectures, and monitoring the

technical efforts of industry partners implementing the upgrades. A key responsibility of the government is to assist in recognizing opportunities for commonality across platforms and to lead the combat system design efforts to implement the product line acquisition approach and architecture. This paper will examine the systems engineering roles of DoD Field Activities and how these roles serve as enablers of the DoD industrial base (prime contractors and industry partners) for the acquisition of Surface Navy Combat Systems.

Introduction

A combat system is an interconnected set of elements (e.g., sensors, weapons, vehicle control, combat management software) designed to accomplish a mission plan and detect, control, engage, and assess functions across all warfighting mission areas (Program Executive Office Integrated Warfare Systems (PEO IWS, 2008). Each Surface Navy platform has a combat system that is used to execute missions assigned to that particular platform. The combat system efforts for each ship class are managed by different program offices that uniquely tailor the combat systems to best meet the set of missions specifically for their ship class. Consequently, the resulting combat systems for each ship class are unique products for a relatively small number of ships. The DoD industrial base is currently employed to design and build each of these platform-unique combat systems. This approach can result in adverse impacts to interoperability, extensibility, mission flexibility, and affordability of the combat systems. The vision for future combat system design and upgrades is to preserve commonality across platforms so that common operational needs are satisfied by common, consistent solutions.

Delivering common Fleet capabilities that are extensible across multiple platforms demands a much greater degree of systems engineering rigor than fielding individual platform combat systems. The DoD Field Activities must conduct performance analysis for the purpose of defining combat system gaps and capabilities; must perform component commonality studies, system requirements development, combat system architecture analysis and development, roadmap development, and independent cost analysis to define what capabilities are required based on Fleet needs and gaps; and must decide which capabilities will be implemented. The products from this analysis will be used to focus the industrial base within a new acquisition approach.

Current State

As illustrated in Figure 1, the current systems engineering process becomes platform-centric very early in the development process as each platform follows its own unique solution path.

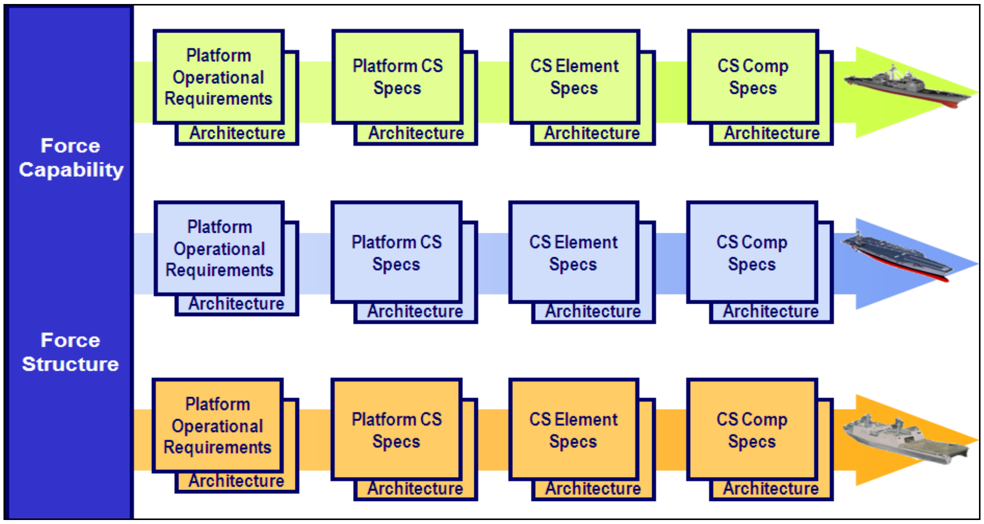

Figure 1. Platform-Centric Systems Engineering Approach

Primary drivers for the differences between the various combat system configurations are the method in which combat systems and system upgrades are acquired and the architecture upon which the combat system design is based. Currently, the resource sponsor defines the operational requirements for a particular combat system or subsystem.

Warfighting or operational requirements for joint and naval forces are initially expressed in the form of very high level Mission Area Initial Capability Documents (MA-ICD) or other capstone statements of mission requirements. For example, a Theater Air and Missile Defense (TAMD) MA-ICD was developed in 2004 to describe desired operational capabilities and perceived warfighting gaps for naval TAMD forces. These desired force capabilities are inherently cross-platform requirements, with a variety of naval and joint platforms cooperating to meet the overall force warfighting need. One of the first steps in upgrading individual combat systems, in response to the MA-ICD, is to extract the capabilities pertaining to a particular combat system and capture the subset of operational requirements for that specific combat system.

For example, a platform-specific operational requirements document (ORD) or capabilities development document (CDD) is generated or updated to capture the operational capabilities applicable to the particular platform. A weakness in the current approach is that each platform performs its own analysis to determine how it should contribute to the overall force mission capability and extracts what it perceives to be the correct subset of MA-ICD capabilities for inclusion in its own platform-specific CDD. Each platform does this in relative isolation from other programs. The resulting CDD then becomes the primary driver for further system specification, architecture, and development.

Funding is provided to each individual program to implement and sustain a system that satisfies operational requirements for that particular system. Once the operational requirements are known, technical programs contract with industry to design, develop, and field systems that satisfy user needs. Each acquisition program is executed in relative isolation, developing their own architectural foundation and combat system design. As a result, the DoD industrial base is contracted to develop platform-specific combat system products that often overlap functionally with similar combat system products for other platforms, leading to both programmatic and operational shortcomings. The government must devise a better methodology for focusing the DoD industrial base to resolve these shortcomings.

Way Ahead

In order to address the shortcomings of the current state, PEO IWS introduced a new approach for the acquisition of platform combat systems and associated components. This new approach is evolutionary in nature, acquiring new surface combat system capabilities and replacing retiring surface combatants through modernization of existing assets from established proven surface combatants. This evolutionary approach to combat system acquisition forms the basis for the development of new mission specific surface combat systems. This approach, which is referred to as the Advanced Capability Build (ACB) approach, is currently being applied to Aegis and the Ship Self-Defense System (SSDS). *The PEO IWS Instruction for the Governance of Surface Navy Combat System Modernization Through Advanced Capability Builds/Technology Insertions* defines ACB as "the capability that is delivered to a specific platform in an integrated combat system package in a effective, safe, reliable, and readily producible manner" (PEO IWS, 2009).

Two key precepts with this approach are government-defined system requirements and government-controlled combat system architecture with a goal of normalizing system requirements and architecture across programs to gain some commonality in software and hardware development. PEO IWS uses the term "Product Line" to define this software and hardware development approach. Figure 2 illustrates this concept of how the product line and common requirements are applied across multiple platforms.

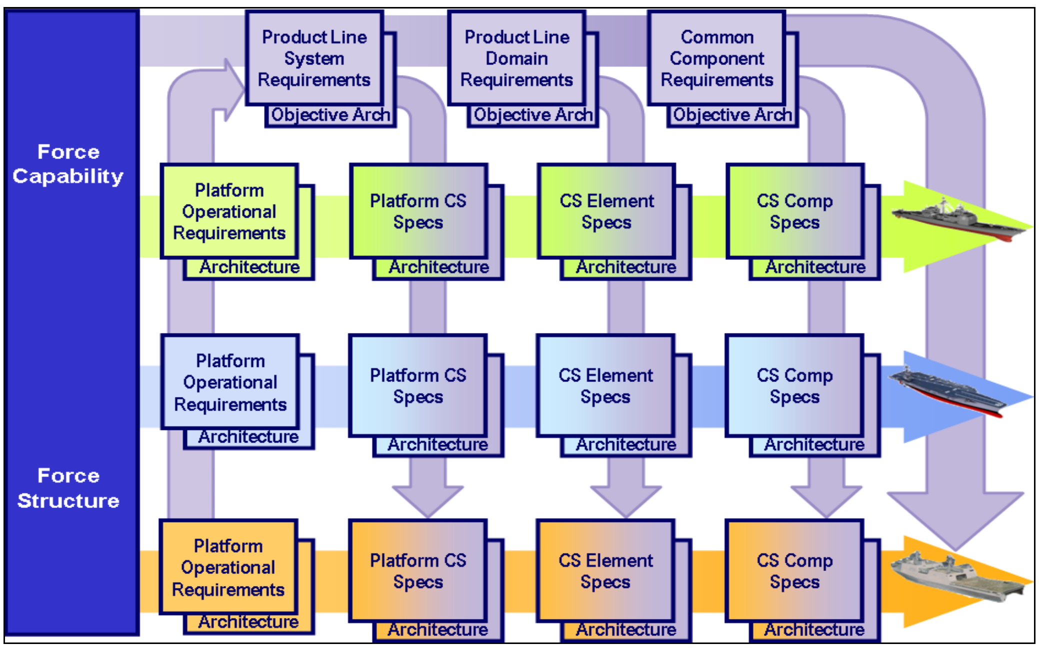

Figure 2. Product Line Approach

This evolutionary approach consists of a single cross-combat system capability planning phase and multiple individual combat system execution phases. PEO IWS oversees a capability planning phase that defines the scope of new capability upgrades and maintenance fixes, the system release to which these improvements will be applied, and the existing development efforts that will be leveraged and integrated to realize these capabilities. This phase commences with a Field Activity-led examination of Fleet needs and gaps, available technology and third party development efforts, and the funding available for these upgrades. Trade studies and prioritizations are conducted to define the actual capability list to be implemented across several ship classes. Further definition focuses on individual components that can be developed as common across these ship classes. This phase concludes with the definition of system-level requirements and architecture products for these specific capabilities, including a successful system requirements review (SRR) for the new integrated capability upgrades. This government-led capability planning phase enables the DoD industrial base to focus on development and integration of capability upgrades with applicability to multiple platforms.

In order to progress through system development and maintain cost and schedule, it is important to exit the capability planning phase and begin execution of development efforts with a well-defined and affordable industry technical work package and combat system capability development approach. Using this work package, DoD industrial base leads the efforts to develop, integrate, and field these combat systems with government oversight.

Focusing the Industrial Base

There are four primary areas in the new acquisition approach that help to focus the efforts of the industrial base. Three of these areas are applicable to the capability planning phase: Combat System Roadmap, Capability Requirements Analysis, and Capability Architecture Analysis. The fourth area is the ACB Execution. Each of these four areas will be described, along with how each helps to focus or enable the DoD industrial base.

Combat System Roadmap

The primary tool used to guide government-led efforts is a Combat System Roadmap, which captures ACB fielding plans across Surface Navy platforms. This PEO IWS-approved roadmap is used to ensure that selected components are being developed based on a common architecture framework and that all components will come together as a system. The roadmap is a concise summary of a planned capability addition or upgrade to a subsystem, component, or element and includes several key features. These key features include the following:

- a listing of additional capabilities or upgrades planned for the system;
- a brief description of the additional capabilities or upgrades;
- a time-phased plan for rolling out the additional capabilities or upgrades, preferably tied to particular ACBs for the targeted host combat system(s);
- any known dependencies or relationships between these capabilities or upgrades and those planned for other related systems, particularly if a package must be delivered together to a combat system platform; and
- funding profiles related to the additional capabilities or upgrades.

The government must work to quantify these features using systems engineering principles. The use of mission thread analysis is a significant part of this. In a conventional mission thread analysis, a particular operational problem or challenge is examined in detail from end-to-end to attempt to determine alternatives and best options for addressing that challenge. The multi-platform mission thread analysis extends conventional analysis by identifying shared operational needs across platforms and evaluating common solutions where appropriate.

The expected performance of current combat systems is determined through analysis of operational effectiveness including such measures as probability of kill of a threat, survival of the examined unit or force, or attainment of mission objectives over time.

Often, this analysis will reveal weaknesses or capability gaps that should be addressed through future combat system product line upgrades. The results of this gap analysis become a more detailed statement of the operational problem and set the stage for identification of options for closing the operational gaps. So, the next step of mission thread analysis is identifying the possible (or leading) options for additional capabilities or upgrades.

Capability enhancements require performance upgrades to multiple combat system elements, so the interdependencies between these elements must be well understood. An understanding of how these element upgrades impact all mission areas is also required. This may require the implementation of multiple elements to achieve single mission improvement, but when applied can actually enhance multiple mission areas. This becomes particularly relevant in the fiscally constrained environment which typically results in a reduction of capability to meet budget.

Understanding how the option or upgrade will be integrated with the combat system is another key factor. This can be conveyed through system architecture and can define interface options as well as multiple concepts of integration. Understanding the various options can give a choice in terms of complexity and, ultimately, cost. This information can be used in trade studies with the metrics supporting the prioritization of capabilities. PEO IWS and DoD Field Activities work together to recommend to the Office of the Chief of Naval Operations (OPNAV) these capability-upgrade candidates for inclusion in an ACB. These decisions initiate the system requirements and architecture definition efforts leading to the SRR. The products of the SRR form the technical work package that focuses the efforts of the industrial base.

Capability Requirements Analysis

As discussed in the previous paragraph, mission thread analysis is essential to the requirements elicitation process. To do this, a detailed operational scenario is first established by OPNAV. The mission thread scenarios themselves depict force-level employment of a system of combat systems to counter the threats under consideration, according to an accepted concept of operations, and from approved sources such as design reference missions for programs slated to receive the combat systems under analysis. Once a set of operationally relevant scenarios is selected for the mission thread analysis, the scenario is examined by the Field Activity using current combat system capabilities and inventories. The expected performance of current combat systems is determined through analysis of operational effectiveness, including such measures as probability of kill, survival of the examined unit or force, or attainment of mission objectives over time. Often, this analysis will reveal weaknesses or capability gaps that should be addressed through future combat system product line upgrades. The results of this gap analysis lead to a more detailed statement of the operational problem for OPNAV and set the stage for identification of technical solutions for PEO IWS.

Requirements analysis is further performed on the top-level cross-platform mission area requirements for a capability using the multi-platform mission thread analysis approach described earlier. This approach views the platforms as swim lanes for the analysis and high-level combat system functions allocated to these platforms in an end-to-end analysis. After a sufficient number of iterations and decomposition of this process, the aggregated functions are then translated into a set of operational requirements for each platform. In this manner, the operational requirements are integrated and deconflicted.

Based on the resulting operational requirements (i.e., CDD), subsequent requirements analysis efforts focus at the system-level to identify common versus unique combat system requirements. Therefore, in addition to allocating operational requirements to each affected system's CDD or NCD in a coordinated manner, those capabilities common across platforms are identified up front. All common requirements are then generated and included in a product line system requirements database that contains the common requirements in context of the common architectural framework across all platforms. Platform-unique requirements continue to be defined by the individual programs. Accordingly, a full system-level requirements specification for each program consists of program-unique requirements and common requirements from the product line system requirements database. These requirements form the basis for what the government will contract with the industrial base to develop, integrate, and field.

Capability Architecture Analysis

The government has a leadership role in the development of combat system level architecture. A System-Subsystem Design Description (SSDD) document is developed by the Field Activity and used to describe the functional and physical architecture of a combat system. This product, coupled with the combat system requirements, is provided to the industry at SRR and is used to define the work package for development.

Development of the SSDD requires additional architecture analysis beyond what is used to define the contents of the ACB. The goal of the architectural analysis is to provide a mapping of the operational requirements onto a system that can deliver the desired capabilities. However, conducting this analysis introduces several new challenges when compared to architectural analysis for a single ship combat system. These challenges include the following:

- assessing and resolving architectural differences between members of the product line,
- developing and upgrading a common product line objective architecture,
- determining appropriate migration plans, and
- integrating architectural plans and schedules between product line members.

The architectural analysis and the requirements analysis are conducted concurrently because the outputs and results of each analysis effort feed the other. At the cross-platform level of analysis, one of the major goals of the architecture effort is to map the required operational capabilities for the force onto the components of the force, which at this level, are the individual ship combat systems. The output of the architecture effort is a partitioned set of requirements, allocated appropriately across the platforms. These partitioned requirements can then be mapped onto each combat system's system-level architecture to come up with the appropriate partitioning of requirements at the system level.

In general, surface combatants are multi-mission platforms. As a result, they can participate in multiple mission areas at the same time. For example, an Aegis combatant routinely supports TAMD, undersea warfare, and strike warfare concurrently. The operational architectures for each of these warfare areas are different but must be woven together into a single, cohesive system design at the platform level. This introduces additional architectural considerations that must be addressed at the system level over and above those mandated when considering the mission operational requirements alone. For example, as Ballistic Missile Defense operational capabilities are integrated, resource and multi-warfare interactions with other air defense requirements of the ship as well as manning constraints and interactions with other mission areas must also be considered.

An objective combat systems product line architectural framework has been defined that should provide the functionality desired, but this architectural vision has not been realized in any of the current product line members. However, initial steps are being taken to move members of the product line towards this architectural goal. For example, common components for track management are under development for use in both the Aegis and the SSDS combat systems. These common components meet the requirements for both platforms as well as conform to the product line architecture. When integrated, they will represent the first tangible results of the product line systems engineering process.

ACB Execution

ACB execution represents the combat system design, development, and fielding phase in the new acquisition approach. The government continues to perform its traditional oversight role and certifies the combat system for operational use and now has the lead for defining the combat system design. The DoD industrial base has the lead for the development, integration, and fielding of the combat system. Because of the efforts during the capability planning phase, the government can focus the industrial base more effectively during the development and integration phases.

During the capability planning phase, the government leads the development of the system level requirements and architecture. As stated earlier, these products form the technical work package for industry, and as such focus the efforts of industry on specific combat system upgrades. The government retains ownership of these products throughout the ACB execution phase.

All design evaluations are performed in context of these products, and any design efforts that drive a change to these products must be adjudicated between government and the industrial base. In this way, the industrial base better understands the expectations of the government, and these expectations have been derived via a top-down, cross-platform analysis effort. Therefore, other individual combat system acquisition efforts will be developing capabilities that are applicable to multiple programs, instead of multiple independent design efforts for similar products. Industry is better able to help solve the programmatic and operational shortcomings of the current state by being focused appropriately by government-led planning, analysis, and definition activities. The ACB execution phase becomes more of a partnership, with expectations better articulated and tangible and objective criteria defined to ensure that the resulting industry-developed products satisfy the government's needs and fit within the boundary conditions to enable use across multiple platforms.

Conclusion

The DoD Field Activity has a unique role in the new Surface Navy Combat Systems Development Strategy. They provide unbiased technical expertise to aid in the decisions made for acquisition. The Field Activities scientists and engineers are able to take a broad look across multiple systems and identify opportunities to implement common requirements and architecture. They are also able to understand the technical detail required by the industrial base to develop and field a system. By using the Field Activities, the DoD industrial base can deliver with the benefit of developing a system that can be applicable to a broader number of platforms while permitting the taxpayer the cost benefit of paying for smarter systems engineering.

Cross-POR systems engineering efforts led by DoD Field Activities is increasing the component-level commonality across Surface Navy Combat Systems. This change in approach away from traditional platform-unique solutions is resulting in efficiencies in technical requirement definition and component design. Field Activities, as enablers of the industrial base, are assisting OPNAV in articulating better defined and firmer requirements; PEO IWS in describing executable product line architecture and common source components to lesson development cost; and industry partners by providing clearly documented system requirements and architecture so they can “build to print.” These DoD Field Activity efforts will provide the government the ability to better focus the DoD industrial base to ensure success of combat system fielding maximizing estimated warfighting value while reducing costly duplicative development efforts.

NSWCDD, like other DoD field activities, will continue to provide technical analysis to support Pre-Milestone B acquisition and Future Years Defense Program (FYDP) budget decisions that focus the industrial base. DoD Field Activities are key to the understanding of technical system knowledge for the DoD operational and acquisition communities and translating that knowledge into achievable capabilities through requirements documents. These documents guide industrial base partners to build the platforms and systems needed by the warfighter. Working together, government, industry, and academia can produce a capable and affordable future for our military.

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