Modular Open Systems Approach

Considerations Impacting Both Acquirer and Supplier Adoption

National Defense Industrial Association

Systems Engineering Architecture Committee

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Abstract

The Systems Architecture Committee of the National Defense Industrial Association (NDIA) System Engineering Division is pleased to provide this white paper with recommendations to government and industry program managers and acquisition professionals regarding the implementation of the Modular Open Systems Approach (MOSA) in new acquisitions. The Architecture Committee consisting of a broad representation of industry, government, and the Services, studied the various facets of MOSA (past and present) in the context of their professional experience in order to provide practical guidance regarding the approach.

In comparison with defense industry designations of MOSA in the past, today's MOSA is seen as a technical design and business strategy used to apply open system concepts to the maximum extent possible, enabling incremental development, enhanced competition, innovation, and interoperability. With this new view, numerous considerations emerge and are presented in this document.

First, a short background and analysis of the current state of MOSA are provided. Then, objectives and concerns are presented based on stakeholder perspectives and lessons learned. Finally, implementation within system architectures and validation of the results are discussed along with other considerations of today's acquisition environment. Throughout the document, our formal recommendations are identified by number along with rationale and supplemental information.

Specific technical and business perspectives of modularity and openness in systems are explored from both acquirer and supplier perspectives using model-based methods to identify and evaluate MOSA characteristics within the context of an integrated architectural model, thereby advancing Digital Transformation for acquisition. Of primary importance was to ensure the discussions and conclusions in this document faithfully adhere to the mandated Congressional legislation (presented in the Appendices as a reference). Consequently, the NDIA recommendations established herein are made in the spirit of honoring this legislation and to identify a means for making MOSA implementations with beneficial outcomes for defense industrial base suppliers and acquirers alike.

Paper Disposition

This paper is formally submitted to the Office of the Deputy Assistant Secretary of Defense for Systems Engineering, ODASD(SE). This paper will also be made available on the National Defense Industrial Association website as a reference resource at https://www.ndia.org. Permission is granted to widely distribute and quote with proper attribution.

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1. Executive Summary

Modular Open Systems Approach (MOSA) can be succinctly defined as "an integrated business and technical strategy to achieve competitive and affordable acquisition and sustainment over the system life cycle". The objective in implementing this approach is to ensure systems are designed, where possible, with highly cohesive, loosely coupled, and severable modules that can be competed separately and acquired from independent vendors. This can allow the DoD to acquire warfighting capabilities, including systems, subsystems, software components, and services with an increased level of flexibility and competition over previous proprietary programs. MOSA implies the use of modular open systems architectures: an existing concept in which system interfaces share common, widely accepted standards.

The main driver for MOSA adoption in new acquisitions stems from the congressional mandate within the 2017 National Defense Authorization Act to use MOSA in major DoD acquisitions by January 2019. Rapid evolution in technology and threats requires a much faster cycle time for fielding and modifying warfighter capabilities, with MOSA having the potential to accelerate and simplify deliveries of new capabilities to meet this need.

This paper discusses important aspects of evolving MOSA principles from both supplier and acquirer perspectives and provides ten (10) recommendations that will assist in successful MOSA adoption within the community. These recommendations are:

1) **Develop MOSA strategy and objectives early in the acquisition process**
2) **Define MOSA implementation approach (acquirer and supplier roles)**
3) **Define interfaces within the System of Systems in terms of MIL-STD-881D Taxonomy Levels of Detail and leverage existing Open System Architectures for lower levels of detail**
4) **Apply MOSA in software architectures at appropriate levels of abstraction and complexity**
5) **Implement MOSA as part of a larger and more robust Digital Engineering strategy**
6) **Incorporate cybersecurity strategy in a MOSA application at the time of initial design, not as a later addition**
7) **DOD and industry work together to define how to evaluate MOSA**
8) **Develop and implement enablers with appropriate investment to affect culture change required for successful widespread adoption of MOSA**
9) **Create Library of MOSA Systems and Interfaces**
10) **Define a means for comparing and specifying standards and interfaces for a MOSA-enabled environment.**

Key enablers for these recommendations include: development of standards and interfaces, detailed Service implementation plans, formal ways of assessing MOSA implementations and a transition by government and industry to a MOSA culture that recognizes and rewards implementation of modular architectures and open interfaces.

2. Preface

2.1 Overview

MOSA is not a new concept. It has been in the defense vernacular and expressed in program development requirements in various forms (e.g., Open Systems Approach or OSA) for several decades. What's different at this point in time is that the hallmarks of MOSA, which were previously only considered in the context a system's *architecture* (i.e., modular open systems *architecture*), now refer to an over-all *approach* to modularity and openness with both technical *and* business ramifications. Hence, a broader relevance of today's MOSA impacts stakeholders in ways which may have been obscure in the past but now are in the forefront of concern – and motivates stakeholders by being codified in law.

When implemented properly, MOSA can be an enabler of significant benefits to both acquirers and suppliers in the DoD-5000 Acquisition Management System. As discussed in this paper, the benefits can be spread more uniformly among the stakeholders resulting in win-win scenarios. Conversely, blanket or vague requests for contractors "to conform to MOSA" can create confusion and may not yield adequate MOSA architectures and other outcomes intended to facilitate MOSA benefits. The NDIA Systems Engineering (SE) Committee recommends a joint collaboration between industry and the government to define the value of MOSA, properly assess it, and improve it over time to ensure lasting success. Details of this consideration are established herein and form the basis of further opportunities and white paper recommendations.

A MOSA approach to procurement has the potential to dramatically reduce cost, increase competition, and deliver new capabilities and systems "at the speed of relevance". Its relevance may span from individual system element implementation to a broader system context of Mission Engineering. As Mission Engineering brings more and more large, complex systems together to create new synergistic capabilities, system integration becomes more complex and challenging. To mitigate these adverse effects, MOSA can facilitate complex integrations of systems used in a mission by defining standard functional partitioning and associated interfaces to ensure that the components are well-defined, compatible, and accessible. Points made herein will support a position that system relevance and value at any level in a design can be increased if modularity and openness are accommodated in a strategic and thoughtful manner.

To ensure a balanced perspective, the benefits and pitfalls with MOSA implementation are identified from both the acquirer (i.e., Department of Defense) and supplier (i.e., defense industrial base member contractors) perspectives. These insights are integral to the recommendations made for prospective leaders charged with implementing MOSA. Armed with this information, the NDIA expects that *all* stakeholders in a MOSA implementation can achieve a higher potential for success and realize both the technical *and* business benefits from such implementations on system development programs and deployments.

2.2 Intended Audience

The intended audience for this paper is <u>anyone considering a business model</u> or involvement with an acquisition entailing MOSA. Reference is made to Figure 1-1 below, representing the Office of the Secretary of Defense's (OSD) perspective regarding the various technical design and business approaches (the "What's") which underpin MOSA for achieving its five primary benefits. <u>Procurement officials</u> need to be especially attentive to ensuring MOSA objectives and evaluation criteria are well defined and understood in alignment with their long- and short-term needs. They must also understand how MOSA is implemented by industry and the Services. <u>Stakeholders involved with Intellectual Property (IP) development</u>, ownership, and management begin to recognize the significant value which can be unlocked by MOSA without encountering potential threats to business models and investments. Better definition of IP ramifications and contractor incentives will also help inform the development community and encourage industry investment in MOSA architectures, processes, tools, as well as advanced technology. It is anticipated that the recommendations in this paper will help inform policy creation across the acquisition landscape and identify approaches to eliminating some of the roadblocks to implementing MOSA today. The recommendations provided can also be used to create a roadmap of how the NDIA can help further define the policies, processes, tools, and approaches needed for MOSA implementation.
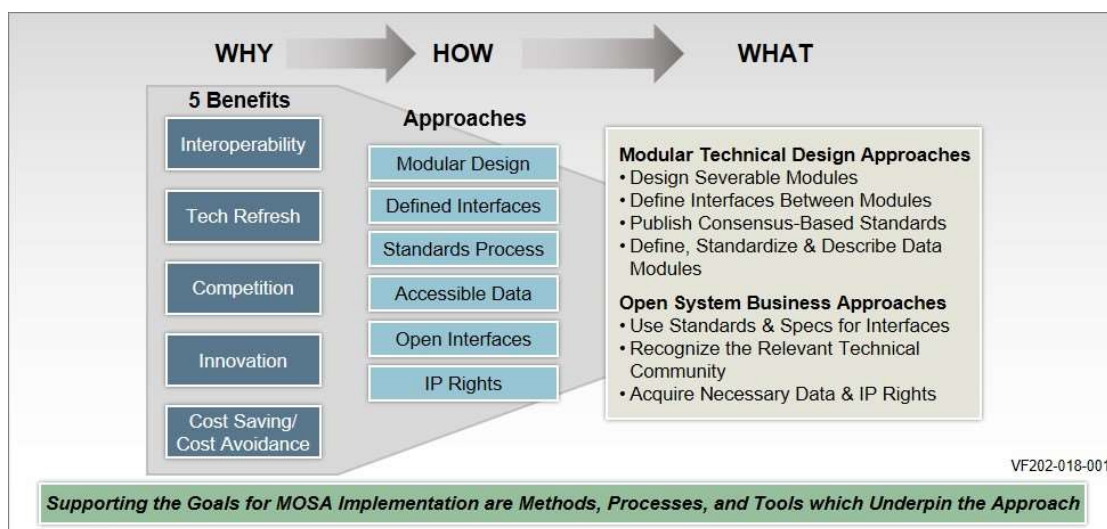
Figure 2-1: Approaches Supporting the Goals for MOSA Implementation

3. Background

3.1 Overview

The National Defense Industrial Association appreciates the value that MOSA can bring to both customer and defense industrial base members by requiring an increased specificity for design. It further understands the sub-par outcomes that legacy modularity and openness attempts have yielded, potentially desensitizing decision makers and other participants to the objectives of MOSA in the process. Given that, today's fiscal realities are factored into the discussions and

conclusions in this white paper in order to reflect the latest, most comprehensive understanding of today's MOSA environment. Specific recommendations identified here-in emerged from the decomposition of MOSA success factors that result from implementation considerations and are driven by underlying MOSA requirements and dependencies.

In a nutshell, *MOSA success* in the future requires a careful balance between business objectives of a strong defense industrial base and the enduring and increased urgencies of the defense organizations supporting the warfighter. This balance can be achieved when the considerations that each party brings to the table are systematically evaluated, tailored, and adjudicated for achieving the "right" level of modularity and "correct" degree of openness for the particular application. It is at that point where success is reached: where the modularity principles supporting the needs for a solution are matched with the openness agreements of the business participants.

To date, *MOSA implementations* have largely been considered in the context of a single system's architecture rather than recognizing the actual complexity of DoD's total System of Systems (SoS) Architecture. The complexity of DoDs total SoS can be thought of as consisting of many "Tiers" from platforms to major systems, to sub-systems, to component modules, and to software modules **(Recommendations #3 and #4)**. In recognizing the many potential tiers in a DoD system of systems, it then becomes evident that ***MOSA characteristics, measures of merit and potential acquisition requirements may vary depending upon the Tier***.

MOSA's primary requirements, entailing Modularity and Openness, are not a "one size fits all" proposition. These dependencies and the associated differences are recognized throughout this paper. There are a great many existing Open Systems Architectures and Standards that are immediately available that can facilitate meeting the goals of MOSA, but these OSAs and Standards must first be appropriately assessed for applicability to the architecture under consideration **(Recommendation #10)**. Currently, there are hundreds of standards in existence or in development. Hence, it can be difficult for a program manager to determine which ones are appropriate for a given procurement, especially given the overlap of many of the standards. Industry and Government need to work together to develop a common means of assessing and comparing standards, determining overlaps and where gaps exist.

3.2 Key Concepts

MOSA is an integrated business and technical strategy that employs a modular design with defined interfaces between modules and if available and suitable, uses open interfaces that are defined by widely supported standards. Use of open interfaces can foster competition and reduce system costs for the acquirer. Use of standards for open interfaces also allows a standardized verification process to ensure interfaces are correctly implemented across different platforms and among different developers. Contractors and suppliers stand to gain as well, largely from increased business opportunities that a uniform MOSA application will provide.

A modular architecture defines the levels of design where functionality is partitioned into discrete, self-contained units with well-defined interfaces. The best modules typically are ones that have a high functional cohesion within the module and a loose coupling between modules at the interfaces. This then permits substitution of similar modules from alternate sources with minimal

impact on the overall system. Such an architecture allows for <u>increased competition and innovation</u> and can provide <u>cost savings</u>, <u>faster deployment</u> of new capabilities and a well-defined path for <u>system upgrades and technology refresh</u>.

MOSA can also provide for <u>increased system interoperability</u>, and in so doing, facilitate <u>Mission Engineering</u> and more capable Systems of Systems which more rapidly <u>adapt to new threats and emerging technologies</u>. These principles can be <u>applied at all levels</u> of the systems, from a top level system of systems, mission level to lower level, sub tier components. However, as identified in this white paper and the associated recommendations, it is vitally important that MOSA implementations be <u>tailored for the specific level of system</u> interest in order to maximize the probability of successful outcomes.

4. Objectives & Concerns

The latest DoD 5000.2 dated Jan 7, 2015 mandates that "Program management is responsible for evaluating and implementing a MOSA to the maximum extent feasible and cost effective. This approach integrates technical requirements with contracting mechanisms and legal considerations to support a more rapid evolution of capabilities and technologies throughout the product life cycle through the use of architecture modularity, open systems standards, and appropriate business practices."

The adoption and implementation of MOSA requires government leadership, through Acquisition guidance, as well as implementation of Open Systems Management (OSM) processes throughout the full program lifecycle. The approach should contain process documentation describing components, interfaces, data (IP) rights, and software licenses at the appropriate levels for upgradeability and interchangeability, along with long-term supportability consistent with government objectives. MOSA is more than defining architectures via documented standards and therefore requires direct management and leadership through all levels of an organization.

4.1 MOSA Benefits and Expectations

As systems become more and more complex, MOSA principles can become more effective in increasing competition and enabling new missions with existing or expanded capabilities. Government and industry objectives are compatible, but with different perspectives, motivations, and perceived benefits. Government/Acquirer benefits include:

1. Increased interoperability between systems and ability to develop new missions through composition and reuse
2. Increased innovation and ability to quickly integrate new capabilities
3. Increased competition between suppliers due to open interfaces
4. Reduced cost and increased buying power
5. Faster and better defined technology refresh capabilities
6. Simplification of the acquisition process

Meanwhile, industry/supplier objectives and benefits are associated with being more competitive and creating shareholder value. Benefits to members of the defense industrial base include:

1. More competitive products through lower cost structures
2. Faster time to market, with less development time and costs
3. Increased competition within supply chain for lower costs
4. Increased interoperability providing greater market opportunities
5. Structured upgrade paths for quicker tech refresh and longer product life spans
6. Foundation for greater commonality across products, and larger lot buys for reduced costs through modularity
7. Incentive to innovate via an improved IP policy, by allowing access to and integration of critical supplier IP while still protecting supplier business interests and investments.

Though different in objectives, both acquirer and supplier alike stand to gain numerous benefits from MOSA, thereby motivating them to strategically plan and tactically implement MOSA capabilities early in an acquisition lifecycle **(Recommendation #1).**

4.2 Acquirer Objectives & Concerns

Acquirers of systems intended to incorporate MOSA features must set the tone and expectations of the acquisition early in the solicitation process. This will help ensure that the expected level of modularity and openness can be designed into the solution rather than "bolted on" later in the product's development (which would increase the odds of a sub-optimal outcome).

In order to maximize the benefits of MOSA in an acquisition, the strategy of the acquirer should be to receive systems designed with a full complement of modularity and openness features. To sustain this benefit, the acquirer should invest in the evolution of reference architectures, capability environments, and suites of adherence standards enhance MOSA adoption. More specifically, the Services, or Department as a whole, should invest in existing (or stand up new) offices coordinating the development of reference architectures and standards. In addition, synchronization of these efforts must continue in order to ensure that each of these environments, suites, and architectures are interoperable with one another. Though each of the Services has made strides in providing recommended contract language, improvement can be made in the awareness of open/common standardization efforts and IP guidance. They should additionally shift initial IP discussions to a point earlier in the acquisition process and ensure that these initial conversations between acquirer and supplier occur at a higher, more strategic level **(Recommendation #2)**. This earlier, higher level coordination will ensure both parties clearly understand the intent of the acquirer as well as allow suppliers to plan and prepare accordingly, therefore improving the likelihood of a win-win outcome.

The acquirer must also leave room for innovation and a competitive marketplace. In order to do this, the environments and architectures desired by the acquirer must consistently limit design requirements only to physical and logical interfaces, data models, message schemas, and other information sharing methodologies. Specific methods regarding how the systems are developed or the involvement of unique trade practices, should not be dictated as part of requirements. By ensuring this subtle difference is understood and maintained, the "secret-sauce" or innovative spirit

of the developer can be maintained by openly sharing how information is exchanged across inter-module interfaces, and what that the information looks like, but retaining ownership of how that information was generated within the modular entities that make up the system.

In the early phases of a program, MOSA procurement objectives should be defined by the acquirer in order to evaluate technical modularity and openness conformance parameters. Ideally, the acquirer will align its modular partitioning with pre-existing standards **(Recommendation #3)** based on an informed set of choices as to the applicability of existing Open Systems Architectures or Standards **(Recommendation #10)**. The acquirer must also clearly define or approve where modular partitioning of the system should exist (e.g., the key interfaces); what system components the acquirer intends to potentially replace in the future; and what interface standards, data model relationships, messaging schema, etc. should be incorporated in the various elements. These can be defined within a model or a checklist to apply a quantitative measure of MOSA which would satisfy the government's interest in saving money and accelerating capability deployments. Once these MOSA objectives and tactics are factored into the acquisition, companies, in turn, will need to balance them with their interests of delivering a solution that meets requirements, satisfies user needs, and generates a fair profit. *A successful MOSA implementation creates a Win-Win Situation for both the acquirers and suppliers alike.* (For additional insights into industry needs, refer to Section 12: Survey of What Industry Needs from OSD).

The acquirer must clearly articulate the upgrade/sustainment plan for the system, in order to justify the IP rights requirements. If the plan is to upgrade system modules later, there is no requirement for full IP rights -- only the adherence to open interfaces and define the required functionality. This can be explained using the MOSA "Gray Box" concept. In this concept, the OSA is made up of modular entities (which encapsulate functions that exhibit behaviors), and interact with one another via open/standardized interfaces. Functions and behaviors of the modular entities in an OSA are known (so they are not "black boxes" -- they are "gray boxes"). The acquirer that wishes to replace (upgrade) a module later, needs to know the functionality (the "what") and the module's open interfaces, but does not need to know how the implementation was achieved -- analogous to replacing a lightbulb where one doesn't need to know the "secret sauce" that the original vendor used to make the tungsten filament. Therefore, MOSA allows the developer to protect their IP -- and therefore removes disincentives for investment in innovative solutions.

Finally, MOSA strategy could exploit another Systems Engineering endeavor in the Dept. of Defense: Mission Engineering. Mission Engineering is defined as *deliberate planning, analyzing, organizing, and integrating of current and emerging operational and system capabilities to achieve desired warfighting mission effects*. When implemented together, MOSA and model-based environments enable systems to be specified, designed, tested, verified, simulated, and cost-estimated, prior to being physically realized. The synergy achieved from evaluating and optimizing a system in the virtual modeling environment in conjunction with physical realizations of modularity and openness provides yet more compelling and enduring benefits. Hence, these two efforts build off of each other and could revolutionize the design and acquisition of systems. The acquiring community has a responsibility to invest in, commit to, and foster a culture that embraces both MOSA and Mission Engineering **(Recommendation #8)**.

4.3 Supplier Objectives & Concerns

Developers and suppliers have the responsibility of implementing MOSA in the articulation of the final system design. While their interests are directed in achieving a solution which meets requirements and best meets user needs while also allowing them to make a reasonable profit, they must consider additional objectives in incorporating MOSA principles. According to the Program Manager's Guidebook, the suppliers are responsible for:

- Providing an enabling environment

- Employing modular design

- Designating key interfaces

- Using open systems architectures and standards whenever possible

- Certify Conformance

Together with acquirers, suppliers must develop measures and metrics for MOSA evaluation which facilitates their making a convincing case and mutual agreement that MOSA objectives have been met in the proposed or finished design. Measurement methods that tie MOSA evaluations to the MOSA objectives ensure that the resulting architecture is optimized around the right qualities and design elements and that contractors know how proposals will be evaluated **(Recommendation #7).**

The supplier provides an enabling environment through incorporating MOSA principles and practices into the program's management plans such as the Program Management Plan; Systems Engineering Management Plan (SEMP), Test and Evaluation Master Plan (TEMP), Subcontracts Management Plan, etc. Consistent with acquirer expectations for providing an enabling environment (e.g., ensuring the procurement process is aligned with MOSA in areas such as data/IP rights, procurement model, and contracting language), specific practices include: conducting data rights and IP reviews of potential solution elements during development of the physical architecture; flowing down MOSA requirements, constraints, and tasks to subcontractors and vendors through subcontracts; and refining requirements specifications, and defining/executing statements of work,

With MOSA objectives and architecture preferably defined prior to release of an RFP, program execution should involve technical reviews that have been adapted to examine the adherence to MOSA implementation requirements throughout the DoDi-5000.02 Acquisition Management System. This entails defining interim steps to meet MOSA procurement objectives while consistently evaluating levels of conformance to both modularity and openness that relate to the initial objectives. A model could possibly be utilized to determine the degree of openness of interfaces in a system development, much along the lines of the Technology Readiness Level (TRL) method of determination.

When implementing MOSA, maximum benefit to suppliers would be achieved by having the Openness strategy defined as early in the acquisition process as possible **(Recommendation #1).** Modular, open system design enables the flexibility to simplify later modifications to systems and allow recombination of existing capabilities and upgrades of system elements across product lines

(product families). This approach fosters innovation and facilitates rapid adaptation of supplier technologies to changing conditions. Designing for modularity is a key technical principle for implementing MOSA and is a complementary piece to the open system practices in contracting. Modular designs meet the broad government objectives for loosely coupled systems that have been developed for interoperability and cost effectiveness, while also meeting supplier business objectives for cost effectiveness, decreased time to market of new solutions, and lower unit costs that are achievable via module re-use within product families.

Technical data rights are important business aspects of MOSA that need to be addressed in the MOSA-enabled acquisition strategy and are of particular concern to suppliers. The DoD Open Systems Architecture Contract Guidebook for Program Managers contains guidance on contract language that should be used in the acquisition of data rights. While primarily a business (not technical) decision, MOSA principles can facilitate the satisfaction of agreements in data rights and future business arrangements by defining where in the system architecture (i.e., within which specific modules) technical data and other proprietary interests are encapsulated and controlled. The supplier should adopt a means for identifying IP included in their architecture where less than full rights are required by the government consistent with the need for future (third-party) upgrades and modifications.

Cybersecurity is another critical component of a MOSA system partitioning strategy which can cut across a complete system concept of operations and design. Open, defined interfaces can increase cyber risk if not addressed early during the architecture development. How the system is architected and "modularized" from the start of development will establish its robustness against cyber threats. Incorporating cybersecurity at later stages of design (commonly referred to as "bolting on" features), misses an opportunity to maximize security effectiveness and threatens the long-term viability of the modular design. An up-front system security analysis as part of the system development will allow the development team mitigate risks and improve robustness in a MOSA system design. **(Recommendation #6)**

When implementing cybersecurity with MOSA in a system, it is important that a risk analysis of the environment be performed. It is equally important that cybersecurity features are incorporated into the architecture along with modularity, openness, and other desired attributes in the development strategy. Ideally, these activities are conducted in the proposal and capture stage of a solution, if not sooner. When doing so, it is important to be cognizant of the supply chain (i.e., suppliers of the suppliers) and associated sourcing of elements. Also, how the resultant system will be used operationally must be understood well enough to ensure that the cybersecurity aspects of the architecture are consistent with the intended CONOPS. As part of the cyber strategy, the appropriate segregation of duties of users, along with data segregation, will allow the system security to be maintained in light of the modularity and openness attributes afforded in the MOSA solution.

4.4 Ensuring MOSA Conformance

A common understanding of what's necessary in MOSA-compliant artifacts is needed in order to ensure fairness and completeness in MOSA evaluation and certification. Hence, a joint government and industry working group needs to come together in order to establish the proper

metrics and approaches that remove ambiguity from the evaluation process. The outcome of such a working group must and ensure that all stakeholders in a MOSA implementation receive appropriate adjudication of subject MOSA artifacts. Such elements would include specific measures for the appropriate level of modularity and openness determinations, along with a process to fully determine satisfaction of MOSA compliance. It would further yield appropriate levels of MOSA relevance to ensure that intellectual IP interests are protected and conveyed, as appropriate, in mutually-agreeable technology and rights transfers.

Objective measurement of the openness of individual interfaces supports the conformance to MOSA, though actual compliance is contingent on the acquirer/supplier agreement. The supplier should also identify an objective means of validating the openness of a module's set of interfaces. Several means have been considered and proposed by the NDIA Architecture Committee though none have been adopted to date. These measurements, combined with the results of system integration and verification, could be used to verify conformance to open standards. In assessing MOSA, it is important to note that the measurement methodology should be emphasized over structure, since a set of *metrics for one domain, such as ship building, may not be appropriate for a different domain, such as aerospace*. **(Recommendation #7)**.

4.5 Architecting for Modularity

For the most part, MOSA has typically been considered in the context of a single system's architecture. However, any single system exists in the context of DoD's complex SoS architecture. The complexity of DoDs total SoS's can be thought of as a taxonomy consisting of many "Tiers" or "Levels" of detail from Joint Force to individual platforms and from organizations to individual systems and sub-systems. This continues to assemblies, modules, components, and parts. Embedded software can occur at any level. *In recognizing the many levels of the DoD SoS's, it is reasonable to assume that MOSA objectives, characteristics, measures of merit and potential acquisition requirements may vary depending upon the system location within the SoS's taxonomy (e.g. mission or functional modules for a composable task force versus composable vehicles and computer programs.)* This taxonomy can be directly related to the "product oriented" work breakdown structure (WBS) of MIL-STD-881D, which is mandated by DoD for cost estimating. See also the OSD Cost Assessment and Program Evaluation (CAPE) (https://www.cape.osd.mil/) guide for organization requirements and program planning.

A more complete discussion of the groups and taxonomy is in section 10.2 This discussion does not pretend to offer a complete lexicon for discussing the levels of granularity but, for the purposes of this paper, provides one way to view and discuss the SoS's.

As a point of clarification, the quality of a modular design cannot just be classified or judged by where it fits in the SoS's taxonomy, but must also consider the modularity design objectives (e.g. producibility, survivability, maintainability, technology refresh and insertion, availability, sustainability, cross-product line re-use for cost savings, etc.). Other factors may also be needed

to fully describe the "what", "where" and "why" a module or architectural partition has been created and identify rationale for associated open interface needs.

4.5.1 Characteristics and Objectives of Modularity

Modularity can be categorized into several types: mission, production, component sharing, maintenance and support. Each type can be decomposed into components that can be mixed and matched into several configurations to meet specific needs. During program execution, the systems engineering process should perform the following tasks:

- Define the types of modularity used on the program;
- Define the functional analysis, physical allocation of the functional architecture, the identification of key interfaces, and how to control them;
- Quantify the degree of modularity through the use of metrics.

Defining overlap of standard interfaces is as important as defining the gaps between standards, but there is no easy way to define the domain applicability of each standard. Further, it can be difficult to decide which standards apply to a particular program, since significant expertise is needed to understand each standard as well as similarities and differences between them. Development of a common method of identifying, assigning, and specifying interfaces or types of interfaces in an architecture along with guidance as to which standards apply is critical in moving forward with gap and overlap analysis in a MOSA-enabled environment **(Recommendation #10).** Augmenting MIL-STD-881D and then mapping interface standards to it could be a method for describing how specific standards are used in any particular development that is consistent with 881D. This mapping would serve as a useful aid to someone interested in maximizing use of standard interfaces but who is unsure what standard alternatives are available.

4.5.2 Implementing Modularity

As discussed previously, it is important to have a plan of approach for implementing modularity in a system design. Forced accommodations of "MOSA- for MOSA's sake" can increase cost and complexity, therefore it is important to understand and explicitly define the expected benefits that a procurement intends to gains through a MOSA strategy. One should pose questions such as:

- Is MOSA being used to:
  - Increase efficiency in manufacturing and production,
  - Facilitate integration at the next Tier up in the system,
  - Allow for rapid technology refresh,
  - Reduce complexity,
  - Increase quality by facilitating specialization,
  - Reduce sustainment costs,
  - Allow for configurable or composable systems,
  - Reduce development time,
  - Stimulate technology or acquisition innovation, or
  - All of the above?

Each objective may require a different approach that drives different objectives and leads to different outcomes. Without understanding the objectives, it is possible to optimize a MOSA architecture around the wrong objectives and possibly increase cost and/or the deployment timeline. The architecture partitioning can be very different depending upon the intended purpose and where the "system" or "component" fits in the taxonomy of the System of Systems. It is important that an RFP include the partitioning above the procurement level, such that Mission Engineering design and external system interfaces are defined and objectives understood by the contractor. Achieving the right balance of modularity, module reusability and performance will require carefully considered tradeoffs that can have large impacts on potential revenue streams and future products. Hence, a compelling business case from both supplier and buyer perspectives needs to be carefully made.

A MOSA strategy should also identify or define other potential impacts including:

- Expected outcomes

- Determinations as to which interfaces need to be open, and who will control them

- Expected standards to be used

- Integration expectations and risks for a level above and a level below the procurement level

- A way to define and quantify supplier success and how MOSA will be evaluated

Regardless of initial inclinations to use MOSA, the Modular Open Systems Approach strategy must be in place prior to RFP release in order to balance modularity and openness needs along with other technical and non-technical considerations, ensuring it is being implemented for the right reasons and positioned to achieve the expected outcomes. Early definition of objectives also allows contractors to plan appropriate technology investments for achieving the right, lowest risk design solution **(Recommendation #1)**.

4.5.2.1 Defining the Approach

All MOSA implementations are not and cannot be created equally. It is our view that MOSA is highly dependent on the SoS's taxonomy level of the system or component under consideration. The nature of the problem that MOSA is attempting to help solve will vary depending on whether the perspective is at the Joint Force level (where ships and Divisions are modules), service-unique perspective, platform perspective (major components or subsystems) or system level perspective (addressing hardware and software modules). As noted earlier, MIL-STD-881D provides a standard way to represent these perspective levels.

For the purposes of this analysis, any system tier level above MIL-STD-881D is considered the purview of Mission engineering. Below that is the primary acquisition perspective, since most materiel contracts are issued at the 881D level and below.

Regardless of the level, how MOSA is managed drives how and who manages the configurations, including the partitions or modules and respective interfaces. Hence, it is imperative that the intent for MOSA be well-understood for each perspective. MOSA implementation architecture at a top level (Enterprise Architecture) such as Joint Force would have different considerations and

objectives for MOSA implementation than lower level elements such as at a circuit card or bracket assembly.

Considering the various levels of modularity possible, numerous stakeholders involved, various sources of requirements and constraints, etc., it is imperative that an MOSA implementation approach guidance be defined for each relevant level of an acquisition, that includes use of common standards, planned partitioning and identification of open interfaces. This plan should also address, where appropriate, methods for sharing of program information and interface data across different programs, services and security levels **(Recommendation #2)**.

4.5.2.2 Placement Considerations of Modules and Interfaces in an SoS

Because of the significant likelihood for confusion regarding placement of modules and interfaces in systems or systems of systems, it is recommended that the DoD community define these "architectural levels" of modularity to eliminate ambiguous terms such as "major system", "major component", and "platform".   Once again, MIL-STD-881D provides a DoD-wide common language and taxonomy important to a common lexicon needed for consistency and precision in discussing the placement of modules and associated interfaces within the hierarchy of SoS's.   The structure of MIL-STD-881D taxonomy levels has an implied numbering convention that is in use in DoD today. The Navy has a standard Ships Work Breakdown Structure (SWBS) that extends the top-level categories of the MIL-STD to many lower levels. For example, 3-digit level would be a radar system (4420), 2-digit is air surveillance system (4400) and 1 digit (4000) is hull, propulsion, command and surveillance, ordnance, etc. MIL-STD-881D only defines the various DoD Platforms to the 2nd digit level. The Acquisition Commands, in turn, produce and maintain the lower levels necessary for their acquisition efforts and evolve the call outs as necessary to reflect technology implementation.

In summary, MIL-STD-881D taxonomy levels of detail provide important infrastructure elements to facilitate MOSA implementation and system integration. It should be used as modules and interfaces are being defined in order to have a consistent approach to defining system hierarchy, a common language, and uniform levels of integration which support all applicable levels in the SoS's taxonomy **(Recommendation #3)**

4.5.2.3 Software Considerations

With software configuration items and software architectures being malleable to modularity and openness principles, significant benefits in a system design may largely be achieved from MOSA implementations of software. MOSA principles applied to software can result in a "Plug & Play" model mindset, providing a compelling case for development of reference architectures and libraries for data model standardization that are relevant to and vary by implementation level **(Recommendation #9).**

Modularity and open system requirements can differ based on the software's purpose and depending on whether the software is embedded, executed as an application, provides a user interface, or provides other specific functionality.   Fundamental software design practice for

MOSA would imply that every module must be able to transmit and receive data to and from any other module that requires it. Publish-Subscribe protocols allow technology to facilitate this implementation.

Modular software enables IP to be protected, residing within a "grey box" at the appropriate implementation level and protecting the interests of the rightful owner. While software design is not well-articulated in MIL-STD-881D, software design taxonomy guidance may be referenced in MIL-HDBK-61A Configuration Management. Using that handbook and/or other best practices, a software development lexicon and/or methodology should be developed for discussing the various levels of software decomposition and design. Standard taxonomies representing common architecture frameworks can then be facilitated (e.g., Standard Structure for Avionics or Shipboard Mission System software). **(Recommendations #4 and #9)**

It is recommended that DoD define a software architectural lexicon and/or reference architecture for discussing the various potential levels of software decomposition and design   These would include declaring MOSA requirements appropriate to software architecture levels of abstraction / reification as well as to the SoS's level, as relevant. Further, a mapping of appropriate standards and guidelines to a reference architecture should be accomplished in order to facilitate comparison of various development environments for their advantages and disadvantages. **(Recommendation #4)**

5. MOSA Evaluation

5.1 Measurement: Openness and Modularity

The diverse nature of the systems being developed by the Services requires great flexibility for assessing Openness and Modularity. As noted earlier, aerospace systems will be significantly different than ship building or satellite design in their approach to MOSA and in particular to openness. A standard approach then is needed that provides flexibility and adaptability while still maintaining credibility, fairness, and the ability to uniformly critique any assessment in a constructive manner. When responding to an RFP, it is important that contractors understand scoring criteria and how MOSA will be evaluated. Any measurement system that's used will need to map to the MOSA objectives developed as part of the MOSA strategy. Increasing modularity for modularity's sake can be detrimental, increasing both cost and complexity. Making a system more modular to allow better Mission Engineering and weapon integration could be a very different architecture from a system where the modularity objectives are to reduce production costs and allow for better upgradeability. If measurement systems do not relate to the MOSA objectives, the resulting architecture and design may be optimized around the wrong design criteria. Primary objectives should not be to optimize a modularity or openness score in a proposal which may lead to an inappropriate architecture. Instead, MOSA architectures should be optimized around the correct objectives and system design criteria; the optimum modularity and openness score should follow.

There are a number of potential approaches to scoring modularity, including using a Technology Readiness Level (TRL)-like approach or the Analytical Hierarchy Processes (AHP) process defined in the Defense Acquisition University course offering CLE 19. It is recommended that Industry and DoD work together to develop an approach that is adequate to map any score back to the defined MOSA objectives **(Recommendation #7)**.

Once modules have been identified, it is important to identify key interfaces, which ones will be open, what standards will be used, and how the interface will be managed. It is important that the criteria for the selection of open interfaces also map back to MOSA objectives. Open standards should also be chosen for non-key interfaces where possible and appropriate. If an international or government standard is not available for an interface selected as being open, a program or domain level standard such as a program level Interface Control Document (ICD) can be used, though that approach is not optimum and may be difficult and expensive to manage. Either way, it is important that the open interfaces be identified early in the development cycle and that the method for developing and managing the interface is also defined. Each of the identified interfaces should be measured for openness using a method such as shown in Table 3-1 to assess both the physical/transport implementation for the interface and the data content standards. The goal is to maximize the Technical Openness Value for key interfaces. It is also recommended that programs include an Open System Management Plan, either as a separate document or as part of the Systems Engineering Plan (SEP). Modularity and openness need to be measured in a fair and consistent way that clearly maps back to the MOSA objectives and ensures that the resulting design will yield an appropriate MOSA architecture that meets customer needs. **(Recommendation #7)**

Table 5-1: Technical Openness Values

Value	Criteria
3	Commercial or DoD Standard
2	Fully disclosed with well-defines and documented design (e.g., program interface ICD)
1	Proprietary interface with good documentation (e.g., MS APIs)
0	Undisclosed Proprietary Interface

By using numerical values, one can quantify the relative values of technical openness across interfaces and compare alternatives to identify which best satisfy Open System Architecture specifications. This also provides a good measure of which interfaces are truly open versus just published or available.

As MOSA compliant systems are developed, it is important that they be made available to the greatest extent possible (e.g., via a library) for reference and follow-on improvement. At a minimum, such information could include the system partitioning architecture as well as the ICDs and standards for the "open" interfaces defined in the system, providing traceability to the driving requirements, MOSA objectives, and processes in the Operational Architectures. This could also include both the modularity objectives and how those objectives were achieved. Availability of such "success stories" and examples will also facilitate development of other common, open architectures and provide access to critical information that will help accelerate MOSA adoption, speed a system's development, and increase competition across industry **(Recommendation #9).**

6. MOSA Considerations for Other Objectives

6.1 Digital Engineering

When used along with a well-formed Acquisition Reference Model (ARM) early in the acquisition lifecycle, Model-Based Engineering and specifically, Model-Based Systems Engineering, can realize all five (5) of the DOD Digital Engineering strategy goals. These goals are:

1. Formalize development,
2. Support integration and use of models,
3. Provide an Authoritative Source of Truth,
4. Establish infrastructure and environment, and
5. Transform culture and workforce

As the government starts to define model based procurement and ownership of the Technical Baseline, MOSA should be included in the broader procurement strategy involving Digital Engineering **(Recommendation #5)**. Initial MOSA architectures should be defined by the government with defense industry participation and then documented as part of the procurement process. This will help ensure that acquisition stakeholders will find their expectations met in both the initial specifications as well as the long-term results of a MOSA implementation.

One way of communicating the RFP content is through the use of models. The Unified Architecture Framework (UAF) Acquisition Reference Model (ARM) described below is a reusable model template used to structure RFP content for consumption and action based on the UAF standard. This template supports data driven decisions beginning with acquisition and maintained throughout the complete lifecycle of program. Frameworks such as UAF support semantic interoperability through the use of a common vocabulary, enabling portfolio and capability management as well as SoS Operational planning and Mission Engineering.

 ARM can be used to communicate unambiguously with suppliers the system being acquired, the data needed for evaluation, the expected form for digital consumption, and guidance on how to use government furnished content. ARM is composed of three (3) major sections as noted in Figure 6-1.
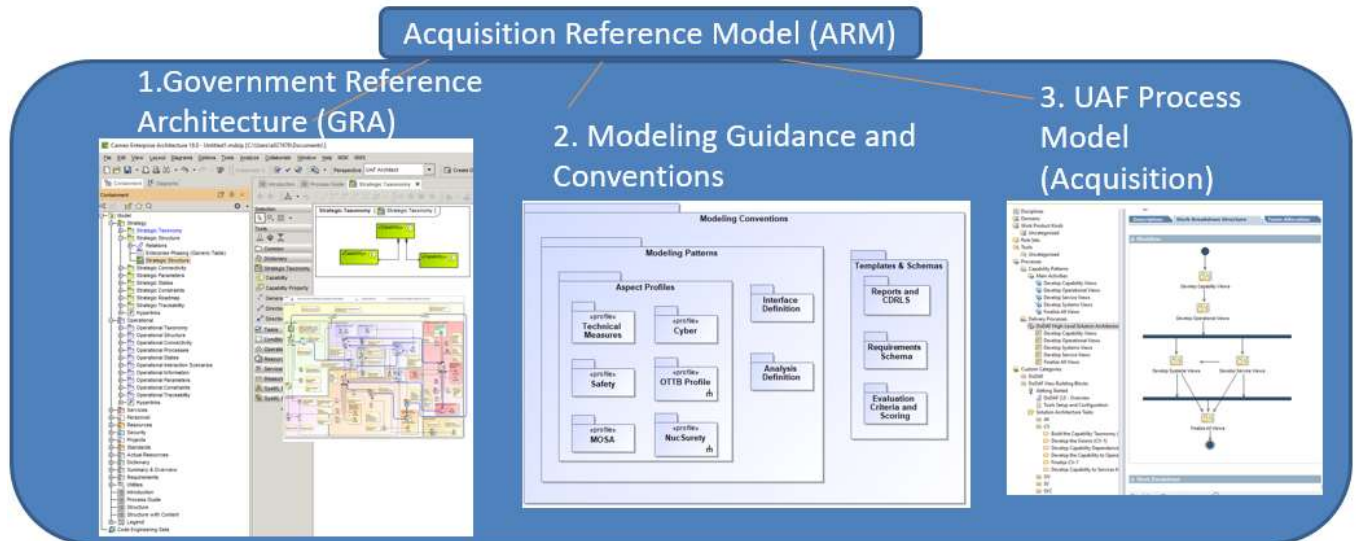
Fig 6-1 Acquisition Reference Model (ARM)

1. The <u>Government Reference Architecture</u> (GRA) is provided to the suppliers to precisely communicate the RFP system context, requirements and constraints. It contains:
    *   High-level Capabilities, mapped to Operational scenarios which are traced to requirements (e.g. CDD, SRD, CONOPS), including the specification and specification tree,
    *   Technical performance measures (e.g. KPPs, KSAs, MOEs…),
    *   Any required architectural partitioning, including structural and functional partitions.

Additionally, the acquirer can use modeling techniques called "tagging" to selectively identify areas that require special MOSA considerations which might impact overall acquisition objectives. This approach can be selectively applied to minimize contractual impact to legacy systems and components. Suppliers can likewise "tag" the RFP response with requested properties such as cost for requested data rights or to highlight contractual discriminators.

2. The <u>Modeling Conventions</u> instruct the suppliers on what and how to provide content to the acquirer so that it can be used for evaluation and validation of a supplier's response. This contains:
    *   Modeling Patterns
        *   Aspect Profiles used to capture specific metrics (i.e. MOSA, Cyber, Safety, Certifications…)
        *   Interface Definitions
        *   Analysis Definitions
    *   Templates & Schemas
        *   Evaluation Criteria & Scoring
        *   CDRLs and DIDs for document generation from models
        *   Requirements Schemas
3. The <u>Enterprise modeling guidance</u> provides instruction for how both the acquirer and supplier can use a selected framework such as DoDAF or UAF, along with any provided profiles for addressing specific aspects such as MOSA tagging.

Using models as an "authoritative source of truth", along with MOSA as a facilitator to Model-Based Systems Engineering (MBSE), will yield corresponding benefits of higher first-time quality from greater attention to modules and interfaces. Initial systems models should reflect well thought out MOSA architectures and taxonomies. A significant advantage of this approach is that MOSA architecture and architecting features, including partitioning, interfaces and standards, functional analyses, and initial CONOPS strategies, lend themselves well to model-based acquisition strategies and constructs.

6.2 Architecture Frameworks

Architecture Frameworks provide conventions, principles and practices for the description of architectures established within a specific domain of application and/or community of stakeholders. ISO/IEC/IEEE 42010:2011 frameworks, such as Unified Architecture Framework, support semantic interoperability through the use of a common vocabulary, thereby enabling portfolio and capability management, SoS operational planning and Mission Engineering.

UAF is method-agnostic and extends the DoD architectural framework (DoDAF) with additional architectural dimensions (i.e. Security, Personnel, Requirements, Analysis, and Simulation with full cross-cutting Traceability via a common semantic vocabulary). UAF, like DoDAF, has a OMG standard implementation, Unified Architecture Framework Profile (UAFP) and Unified Profile for the Department of Defense Architecture Framework (DoDAF)/ United Kingdom Ministry of Defense Architecture Framework (MODAF) (UPDM) respectively, which supports a data-centric, model-based approach for using the frameworks. Figure 6-1 highlights UAF representational formats.

Figure 6-1: UAF Formats

6.3 Mission Engineering and Interoperability Considerations

Interoperability of participating systems in a SoS is of utmost importance for executing the mission. As each member system may contain their own Modularity and Openness attributes, it is via these interfaces at the highest level under consideration where mission capabilities are realized or lost as systems come and go in the system of systems. Modularity and openness principles can be success factors at these highest system levels as well. Therefore, the mission engineering strategy of the DoD and services must include consideration for how well current and future systems support the interoperability needed to achieve synergistic capabilities from the SoS.

One of the DoD *Goals for Digital Engineering* is to "transform the way we do engineering, taking advantage of the computational capability available to us today, recognizing this is a change for the culture and the workforce." Further, Mission Engineering also represents a change to the DoD culture and workforce with the shift from a program/ system focus to a focus on the "mission as the system". In both instances, modularity and openness can be incorporated into digital engineering transformations and mission engineering implementations, from the highest to lowest system levels. With today's rapidly evolving threat environment and changing technology landscape, now the ideal time to consider MOSA principles with Mission Engineering and Digital Engineering across the DoD. See section 10.2.1.1 for additional thoughts in this area.

7. Conclusions

This NDIA MOSA white paper presents technical and business perspectives of modularity and openness in systems from both acquirer and supplier perspectives along with broader implications relating to Digital Engineering, Mission Engineering, IP, Data Rights, and other objectives in today's challenging acquisition environment. It is intended to sharpen today's understanding of MOSA ramifications in order to facilitate reaching a mutually beneficially outcome to stakeholders on both sides of the table, and to enable a MOSA culture that is continually looking for opportunities to increase interoperability and reduce costs of complex DOD systems..

Per the observations, findings, and recommendations described herein, it is clear that the road to successful MOSA implementation is still littered with hazards but also contains pathways to success if navigated carefully. The ten (10) specific NDIA recommendations for implementation of MOSA should be viewed as important waypoints on the journey to finally achieving a lasting MOSA adoption. Each of the recommendations addresses one or more of the factors involved with MOSA, whether involving MOSA strategy in Recommendation 1, implementation tactics in Recommendations 2 – 4, integration factors in Recommendations 5 & 6, MOSA evaluation in Recommendation 7, or MOSA enablers in Recommendations 8 – 10. Collectively, these factors represent the significant system dynamics in play which impact all industry participants.

It will be through on-going relationships between the government customer and industry supplier, facilitated by organizations such as the NDIA, where difficult decisions regarding MOSA impact to business strategies will be made, a common understandings of opportunities enabled will be reached, and successful outcomes will be achieved. The NDIA looks forward to helping facilitate

these advancements so as to realize its lasting benefits in systems of the future, to ensure a healthy defense industrial base, and to provide for the betterment of the country.

8. Recommendations – Detailed Summary

Major defense acquisition programs that receive Milestone A or B approval will require MOSA (per legislation). This paper offers ten specific recommendations to implement a MOSA strategy within the acquisition:

1. Develop MOSA strategy Prior to RFP
   - Understand reason and objectives for MOSA and its application on an acquisition
   - Define supplier success and how MOSA will be evaluated
   - Define MOSA partitioning at a level above the planned procurement system
   - What interfaces and standards are needed for adequate Mission Engineering?
   - Demonstrate understand of financial and performance justification for planned partitioning
   - Provide MOSA strategy early in acquisition cycle to allow contractors to plan technology investments
   - Develop MOSA principles that can facilitate the satisfaction of agreements in data rights and future business arrangements by defining where in the system architecture specific modules involving technical data and other proprietary interests are encapsulated and controlled.

2. Define MOSA implementation approach
   - Define level of MOSA addressed, planned partitioning, functional analysis, interfaces to be controlled/open and the domain in which commonality is desired, as well as the objective for MOSA implementation (adaptability, sustainability, upgradeability, competition, etc) – for each level of design
   - Consider incentives for implementing MOSA in order to facilitate acceptance by acquirers and suppliers
   - Define OSD policy and regulations for implementing Technical Data Rights and IP (those impacted by MOSA)
   - Develop MOSA architecture at level being procured along with governance of planned open interfaces
     - One size does not fit all- MOSA requirements and metrics will vary depending upon:
       - Purpose of MOSA (Production Efficiency, Survivability, Adaptability, Maintainability, Competitive Procurement, Complexity Reduction, etc.)
       - Placement in the System of Systems (SoSs) Taxonomy. (Truck to software component)(Mission Computer Program to Radar Signal Processing Module)
   - Plan for design disclosure of common modules adequate to enable second sourcing and competition

- Identify common standards or release of ICDs and other documents that define open interfaces
- Define methods for sharing of program information and interfaces across services, programs and security levels

3. Define placement of Interfaces and Modules within the System of Systems in Terms of MIL-STD-881D Taxonomy Levels of Detail.
    - MIL-STD-881D is important for establishing a common language
        - Provides consistent approach to defining hierarchy within a system or System of Systems
        - Needs to be employed consistently
    - Define levels of taxonomy/modularity to eliminate ambiguous terms such as "major component" and "platform level"
    - Consider system taxonomy breakdown of the nomenclature system MIL-STD-196F/G (System, Subsystems, Centers, Centrals, Sets, Group, Units) for related taxonomic conventions
    - Define level of integration (Manual, type of automation, etc.) expected between platforms, systems, subsystems, and components at all applicable levels in the SoS's taxonomy

4. Define a software architectural lexicon and/or reference architecture for discussing the various levels of software decomposition and design Apply MOSA requirements appropriate to software architecture levels of abstraction / reification as well as to the SoS level.
    - Apply MOSA requirements appropriate to software architecture levels of abstraction / reification, including the SoS level
    - Develop a software taxonomy similar to MIL-STD-881D (other than current CPCI treatment) to guide development of software MOSA. Especially focus on modularity in software and standard interfaces
    - Define a Framework/Lexicon to enable discussion of the design level with appropriate partitioning at various levels and stages of design and associated logical interfaces.
    - Develop a common reference architecture for data model identification at varying levels of fidelity, including applicability of various partitions in the various DoD Domains
    - Define modular software data rights at appropriate levels of modular abstraction/reification (OS vs. micro-services)

5. Implement MOSA as part of a larger and more robust Digital Engineering strategy
    - Use models to define and communicate MOSA architectures and partitioning
    - Use MOSA to facilitate Model Based Acquisition
    - Develop common MOSA framework/lexicon needs to be tasked to define System Functions at multiple levels of an architecture (Instance data at the next levels below the DoDAF Meta Data of Performer and System).

- Articulate System and SoS Architecture definition and management responsibility needs at the government and mission level, with flow-down to contractors and procurement items.
- Categorize standards, common modules and interfaces as levels in the SoS taxonomy and technology state (old, latest implemented, emerging, etc.), then placed in a reference architecture

6. Incorporate cybersecurity strategy in a MOSA application at the time of initial design, not as a later addition.
   - System Security Engineering needs to be performed up-front as part of the development process (when identifying CONOPS and declaring security requirements)
   - Understand effects of modularity and open interfaces on cybersecurity and system security
   - Understand possible MOSA-induced threat vectors and associated risks
   - Develop security architecture early in the program and define risk mitigation approaches

7. Ensure DoD and industry work together to define how to evaluate MOSA.
   - Define MOSA metrics for various domains and SOS levels
   - Establish MOSA evaluation process and evaluation criteria for proposals
   - Define what it means to be MOSA compliant and develop standard certification objectives and criteria
   - Emphasize measurement methodology over structure (One set of metrics for one domain, e.g. ship building, may not be appropriate for a different domain, e.g. aerospace)

8. Develop and implement enablers with appropriate investment to affect culture change required for successful widespread adoption of MOSA principles.
   - Make MOSA the default approach unless warranted by exceptional circumstances
   - Open Systems Management Plan (OSMP) as common as a SEP
   - MOSA incorporated into technical/management reviews
   - MOSA strategy defined at all levels of the system of systems
   - Government needs to coordinate across services and weapon systems as to specifications, standards, and mission engineering
   - Build MOSA incentives into contracts and award fee structures

9. Create a Library of MOSA Systems and Interfaces.
   - Maintain re-useable archive of systems that are certified MOSA systems and interface types identified as certified MOSA interfaces
   - Make MOSA-compliant systems available for reference and follow-on improvement

- Includes the system partitioning architecture as well as the ICDs and standards for the "open "interfaces defined in the system, providing traceability to the driving requirements and processes in the Operational Architectures.
- Include the modularity objectives, how those objectives were achieved, and why they are important
- Facilitate development of common, open architectures, providing access to critical information that will 1) help accelerate MOSA adoption, 2) speed a system's development, and 3) increase competition across industry
- Develop Common framework, language, process, and standards to allow precision in describing placement of modules and interfaces in the SoSs taxonomy and facilitation in the comparison of various development environments and standards sets.

10. Define a means for comparing and specifying standards and interfaces for a MOSA-enabled environment.
    - Develop method to talk about and compare standards
    - Critical for gap analysis
    - Develop a common method of assigning interfaces or types of interfaces to an architecture
    - Identify one or more tool(s) that can be used by program managers and other stakeholders to determine appropriate standards to use
    - Map standards interfaces to MIL-STD-881D

9. Future Topics

The NDIA Systems Engineering Division Architecture Committee continues to tackle cutting-edge Architecture-related topics. For those associated with MOSA, this organization of government and industry experts expects to consider additional MOSA-related topic areas in the future, including:

a) **Raising awareness and acumen of MOSA user-stakeholders and other stakeholders.** A need to provide guidance and training regarding the implementation, evaluation, and use of MOSA (from both acquirer and supplier perspectives) through-out the systems engineering and design process is imperative for successful infusion of MOSA across the industry. Lessons learned from earlier implementation attempts for MOSA indicate that a base of assertive practitioners is vital to the success of an initiative such as MOSA.

b) **Resolving potential conflicts between MOSA-constrained environments and the IP/Data Rights issues emerging across the defense industry.** Identifying the appropriate level of MOSA implementations on systems without violating IP and associated Data Rights is critical to successful MOSA adoption, particularly with the emergence of Digital Engineering considerations in the midst of a skeptical industrial base (reference work identified as "What the DoD Must Do to Convince the Defense Industry that the DoD is Serious about MOSA").

c) **Adopting portable models which feature MOSA implementations.** Representative models of system elements containing MOSA features (such as adherence to MOSA-related standards), as peculiar to particular product domains (e.g., ship design, air vehicle design, ground vehicle design, missiles, etc.) is key to acceptance and cost-saving reuse objectives for MOSA.

d) **Developing a MOSA-Based RFP Template for proposal solicitations:** This artifact will contain MOSA-compliant basis for solicitation language found in Section L and MOSA-related evaluation criteria found in Section M. It will encourage common perspectives and expectations for acquisitions

e) **Collected Metadata model and tool set implementation examples for data standardizations and taxonomies.** Expect these to be featured in a catalog of various MOSA data representations (e.g., in any architectural framework, they will include certain metadata to standardize taxonomies that relate to each respective architecture). An inventory and cataloging of current architectures which comply with certain MOSA-related standards.

f) **Highlight MOSA Support for Mission Engineering and Digital Engineering:** architecting approaches, interoperability implementations, etc.: Guidelines for applying MOSA principles to Mission Engineering (e.g., System-of-systems considerations) and Digital Engineering (e.g., data flows and relationships).

g) **Establish MOSA standards in Meta Models:** This will include considerations and categories for standard definitions, preferred applications, and "Pick-Lists"

h) **Classify taxonomies in the various frameworks involved with MOSA models:** Establishing groupings of MOSA implementation patterns as relevant to various product domains; specific emphasis for domain-specific applications of MOSA.

i) **Identify architectural tools evolution to support architectures:** This entails tool interoperability, SE tool integration with Engineering design tools, and other process and infrastructure enhancements which facilitate MOSA adoption, implementation, and exploitation.

10. Appendix

10.1 Current legislative Direction

The current legislation affects many aspects of acquisition process.

Section 10.1.1 highlights US Code guidance for MOSA as defined in the paragraph below. Section 10.1.2 contains MOSA mandates from DoD 5000, and Section 10.1.3 contains MOSA guidance from the Defense Acquisition Guidebook.

10.1.1   US Code MOSA Legislation

US Code, Title 10 (Armed Forces), Chapter 144B: Weapon Systems Development and Related Matters, Subchapter 1 – Modular Open System Approach in Development of Weapons Systems. Section references are as follows:

Sec. 2446a. Requirement for modular open system approach in major defense acquisition programs; definitions.

2446b. Requirement to address modular open system approach in program capabilities development and acquisition weapon system design.

2446c. Requirements relating to availability of major system interfaces and support for modular open system approach

10.1.1.1   Section 2446a: Requirement for Modular Open System Approach in Major Defense Acquisition Programs; Definitions

(a) MODULAR OPEN SYSTEM APPROACH REQUIREMENT.- A major defense acquisition program that receives Milestone A or Milestone B approval after January 1, 2019, shall be designed and developed, to the maximum extent practicable, with a modular open system approach to enable incremental development and enhance competition, innovation, and interoperability.

(b) DEFINITIONS.—In this chapter:

    (1) The term ''modular open system approach'' means, with respect to a major defense acquisition program, an integrated business and technical strategy that -

        (A)   employs a modular design that uses major system interfaces between a major system platform and a major system component, between major system components, or between major system platforms;

        (B)   is subjected to verification to ensure major system interfaces comply with, if available and suitable, widely supported and consensus-based standards;

        (C)   uses a system architecture that allows severable major system components at the appropriate level to be incrementally added, removed, or replaced throughout the life cycle of a major system platform to afford opportunities for enhanced competition and innovation while yielding—

            (i)   significant cost savings or avoidance;

            (ii)   schedule reduction;

            (iii)   opportunities for technical upgrades;

            (iv)   increased interoperability, including system of systems interoperability and mission integration; or

            (v)   other benefits during the sustainment phase of a major weapon system; and

        (D)   complies with the technical data rights set forth in section 2320 of the US Code.

    (2) The term "major system platform" means the highest level structure of a major weapon system that is not physically mounted or installed onto a higher level structure and on which a major system component can be physically mounted or installed.

    (3) The term "major system component" -

        (A) means a high level subsystem or assembly, including hardware, software, or an integrated assembly of both, that can be mounted or installed on a major system platform through well-defined major system interfaces; and

(B) includes a subsystem or assembly that is likely to have additional capability requirements, is likely to change because of evolving technology or threat, is needed for interoperability, facilitates incremental deployment of capabilities, or is expected to be replaced by another major system component.

(4) The term "major system interface" -

(A) means a shared boundary between a major system platform and a major system component, between major system components, or between major system platforms, defined by various physical, logical, and functional characteristics, such as electrical, mechanical, fluidic, optical, radio frequency, data, networking, or software elements; and

(B) is characterized clearly in terms of form, function, and the content that flows across the interface in order to enable technological innovation, incremental improvements, integration, and interoperability.

(5) The term "program capability document" means, with respect to a major defense acquisition program, a document that specifies capability requirements for the program, such as a capability development document or a capability production document.

(6) The terms "program cost targets" and "fielding target" have the meanings provided in section 2448a(a) of the US Code.

(7) The term "major defense acquisition program" has the meaning provided in section 2430 of the US Code.

(8) The term "major weapon system" has the meaning provided in section 2379(f) of the US Code

10.1.1.2 Section 2446b: Requirement to Address Modular Open System Approach in Program Capabilities Development and Acquisition Weapon System Design

(a) PROGRAM CAPABILITY DOCUMENT.—A program capability document for a major defense acquisition program shall identify and characterize -

(1) the extent to which requirements for system performance are likely to evolve during the life cycle of the system because of evolving technology, threat, or interoperability needs; and

(2) for requirements that are expected to evolve, the minimum acceptable capability that is necessary for initial operating capability of the major defense acquisition program.

(b) ANALYSIS OF ALTERNATIVES.—The Director of Cost Assessment and Performance Evaluation, in formulating study guidance for analyses of alternatives for major defense acquisition programs and performing such analyses under section 139a(d)(4) of the US Code, shall ensure that any such analysis for a major defense acquisition program includes consideration of evolutionary acquisition, prototyping, and a modular open system approach.

(c) ACQUISITION STRATEGY.—In the case of a major defense acquisition program that uses a modular open system approach, the acquisition strategy required under section 2431a of the US Code shall

    (1) clearly describe the modular open system approach to be used for the program;

    (2) differentiate between the major system platform and major system components being developed under the program, as well as major system components developed outside the program that will be integrated into the major defense acquisition program;

    (3) clearly describe the evolution of major system components that are anticipated to be added, removed, or replaced in subsequent increments;

    (4) identify additional major system components that may be added later in the life cycle of the major system platform;

    (5) clearly describe how IP and related issues, such as technical data deliverables, that are necessary to support a modular open system approach, will be addressed; and

    (6) clearly describe the approach to systems integration and systems-level configuration management to ensure mission and information assurance.

(d) REQUEST FOR PROPOSALS.—The milestone decision authority for a major defense acquisition program that uses a modular open system approach shall ensure that a request for proposals for the development or production phases of the program shall describe the modular open system approach and the minimum set of major system components that must be included in the design of the major defense acquisition program.

(e) MILESTONE B.—A major defense acquisition program may not receive Milestone B approval under section 2366b of the US Code until the milestone decision authority determines in writing that -

    (1) in the case of a program that uses a modular open system approach -

        (A) the program incorporates clearly defined major system interfaces between the major system platform and major system components, between major system components, and between major system platforms;

        (B) such major system interfaces are consistent with the widely supported and consensus based standards that exist at the time of the milestone decision, unless such standards are unavailable or unsuitable for particular major system interfaces; and

        (C) the government has arranged to obtain appropriate and necessary IP rights with respect to such major system interfaces upon completion of the development of the major system platform; or

    (2) in the case of a program that does not use a modular open system approach, that the use of a modular open system approach is not practicable.

10.1.1.3 Section 2446c: Requirements Relating to Availability of Major System Interfaces and Support for Modular Open System Approach

The Secretary of each military department shall -

(1) coordinate with the other military departments, the defense agencies, defense and other private sector entities, national standards setting organizations, and, when appropriate, with elements of the intelligence community with respect to the specification, identification, development, and maintenance of major system interfaces and standards for use in major system platforms, where practicable;

(2) ensure that major system interfaces incorporate commercial standards and other widely supported consensus-based standards that are validated, published, and maintained by recognized standards organizations to the maximum extent practicable;

(3) ensure that sufficient systems engineering and development expertise and resources are available to support the use of a modular open system approach in requirements development and acquisition program planning;

(4) ensure that necessary planning, programming, and budgeting resources are provided to specify, identify, develop, and sustain the modular open system approach, associated major system interfaces, systems integration, and any additional program activities necessary to sustain innovation and interoperability; and

(5) ensure that adequate training in the use of a modular open system approach is provided to members of the requirements and acquisition workforce.

10.1.2 DoD 5000 Mandates for MOSA

Enclosure 3: 14. MODULAR OPEN SYSTEMS APPROACH

Program Managers, with support from the Lead Systems Engineer, are responsible for applying modular approaches (DAG CH 3–2.4.1.) in product designs where feasible and cost-effective. They are also responsible for acquiring data and IP that are both appropriate (10 U.S.C. 2320 (Reference (h)) and essential to achieving the expected benefits (see paragraphs 6a(4) and 6a(5) in Enclosure 2 of this instruction for additional information on MOSA and IP). Modular designs coupled with an appropriately open business model provide a valuable mechanism for continuing competition and incremental upgrades, and to facilitate reuse across the joint force.

Enclosure 2: 6.a.(3) Competition.

The Acquisition Strategy will address how program management will create and sustain a competitive environment, from program inception through sustainment. Program management should use both direct competition at various levels and indirect means to create competitive environments that encourage improved performance and cost control. Decisions made in the early phases of the acquisition process can either improve or reduce program management's ability to maintain a competitive environment throughout the life cycle of a program. Strategies to be considered include: competitive prototyping, dual sourcing, and a modular open systems approach (MOSA) that enable competition for upgrades, acquisition of complete technical data packages,

and competition at the subsystem level. This also includes providing opportunities for small business and organizations employing the disabled.

Enclosure 2: 6.a.(5) MOSA.

Program management is responsible for evaluating and implementing a MOSA to the maximum extent feasible and cost effective. This approach integrates technical requirements with contracting mechanisms and legal considerations to support a more rapid evolution of capabilities and technologies throughout the product life cycle through the use of architecture modularity, open systems standards, and appropriate business practices. The Acquisition Strategy for the system should identify where, why, and how a MOSA will or will not be used in the program.

10.1.3 MOSA Guidance from the Defense Acquisition Guidebook

Section H 3–2.4.1 Modular Open Systems Approach

A modular open systems approach is defined as an acquisition and design strategy consisting of a technical architecture that adopts open standards and supports a modular, loosely coupled and highly cohesive system structure. This modular open architecture includes publishing of key interfaces within the system and relevant design disclosure. The key enabler for MOSA is the adoption of an open business model that requires doing business in a transparent way that leverages the collaborative innovation of numerous participants across the enterprise, permitting shared risk, maximized reuse of assets and reduced total ownership costs. The combination of open systems architecture and an open business model permits the acquisition of systems that are modular and interoperable, allowing for system elements to be added, modified, replaced, removed and/or supported by different vendors throughout the life cycle in order to afford opportunities for enhanced competition and innovation. MOSA is not an end result sought by the warfighter or end-item user; it is an approach to system design that can enable additional characteristics in the end item.

DoD identifies the primary benefits of MOSA as:
- Increased interoperability
- Enhanced competition
- Facilitation of technology refresh
- Increased innovation
- Potential cost savings or cost avoidance

MOSA benefits Program Managers (PMs) by using a general set of principles to help manage system complexity by breaking up complex systems into discrete pieces, which can then communicate with one another through well-defined interfaces. In this way, MOSA is broadly defined and inclusive of a variety of tools and practices.

Acquisition programs adopting MOSA may benefit from:
- Reduced life-cycle costs without sacrificing capability
- Reduced reliance on single-source vendors ("Vendor Lock")
- Shortened program acquisition timeline
- Enhanced rapid and agile development
- Accelerated transition from science and technology into acquisition due to modular insertion
- Increased ability and flexibility to retrofit/upgrade system elements for new/evolving capability
- Enhanced incremental approach to capabilities
- Increased competition and innovation
- Enhanced ability to create security structures within a design to reduce security risk

MOSA may also benefit warfighters by:
- Reducing operator learning curves by using systems that have similar functions and are operated in similar ways, thereby reducing costs
- Increasing interchangeability
- Reducing support and sustainment costs

Although a PM may employ MOSA to achieve some or all of these benefits, the methods the PM's staff uses, and the associated business implications, can vary widely and may drive different techniques and additional responsibilities into programs. The implementation strategy chosen should consider both impacts to the program and to the system's performance (e.g., its effectiveness and feasibility). These factors underpin the Department's policy for MOSA in acquisition.

DoDI 5000.02, Enc 2, sec. 6a and DoDI 5000.02, Enc 3, sec. 14 direct PMs to evaluate and implement MOSA where feasible and cost-effective. The USD(AT&L) memorandum, "Better Buying Power 2.0: Continuing the Pursuit for Greater Efficiency and Productivity in Defense Spending," November 13, 2012, raises the relevance of MOSA along with the acquisition of data rights for appropriate system elements. The overarching business case for DoD is increasing the level of competition by enabling small and large businesses to participate in competition for new or upgraded capabilities. Programs should develop a business model, documenting the strategy for use of MOSA and associated data rights.

The DoD Open Systems Architecture Contract Guidebook for Program Managers contains guidance regarding contract language programs should use to acquire data rights in support of a program's MOSA strategy. Additional information and supporting details amplifying each aspect of MOSA are available on the DASD(SE) website.

The PM should:
- Establish supportive requirements; business practices; and technology development, acquisition, test and evaluation and product support strategies for effective development of open systems

- Ensure data deliverables support the IP Strategy (see Acquisition Strategy template) and secure the necessary data rights to support and sustain the system.
- Map modular open systems strategy and functional architecture to Statement of Work (SOW) requirements, Data Item Descriptions (DID) and Contract Data Requirements List (CDRL) items consistently across the enterprise.
- Ensure compliance.
- Consider including MOSA as one of the evaluation criteria for contract proposals.
- Determine the appropriateness of MOSA by considering software constraints, security requirements and procedures, availability and cost of data rights, life-cycle affordability and reliability of open standards, as well as other relevant factors such as environmental constraints (e.g., temperature, humidity) and environment, safety and occupational health (ESOH) considerations

The Systems Engineer should:
- Employ an overall plan for MOSA that supports the system functional architecture and uses prescribed USD(AT&L) business case analyses
- Ensure the system functional architecture is structured to accommodate Open Systems Architecture (OSA) where feasible, due to the high potential for reduced risk and cost
- Assess performance
- Balance current implementation of MOSA with performance and evolving technology at the physical level; MOSA establishes a technical baseline that may support modular architecture, but formally constrains the interfaces between modules, where interfaces close to current performance limits may quickly become obsolete
- Evaluate the technical appropriateness of MOSA by considering software constraints, security requirements and procedures, availability and cost of data rights, life-cycle affordability and reliability of open standards, as well as other relevant factors, such as environmental constraints (e.g., temperature, humidity) and ESOH considerations
- Open systems benefits may not be realized without deliberate planning and guidance at the Program Executive Office (PEO) level. Re-use may be challenging if open systems and software on other systems (even other open systems) are not developed and modularized in a common fashion. As an example, an aviation platform may develop an Automatic Dependent Surveillance-Broadcast (ADS-B) software application that is MOSA conformant, but that application may never be re-used by a sister platform that may have its ADS-B and Tactical air navigation software combined in a single module.

Modular open system designs, developed from the system architecture, should be analyzed at each design review because there is a link between MOSA and the level and type of technical data, computer software and data rights the government needs for life-cycle support. In many cases weapon systems using MOSA system elements can have increased opportunities for competitive sourcing during the life-cycle sustainment, and a correspondingly lesser need for detailed design data and associated data rights. This benefit enables an incremental approach to capability adaptation in MOSA-enabled systems and is a benefit of the modularity originally specified in the functional architecture.

The engineering trade analyses conducted prior to Milestone B help determine which system elements can be adapted to MOSA in order to reduce program cost and development time lines.

Correct application of MOSA principles and practices results in modular system elements having well-defined functions and open standards-based interfaces. Threat analyses, functional criticality analyses, technology opportunities and evolved capability assessments are examples of assessments against the functional architecture to determine which system elements should be MOSA-enabled. When these system elements require an upgrade, replacement should be competitive, faster and cheaper because the MOSA-enabled system elements are modular. Because system functional architecture maps from the higher-level enterprise architecture, engineering trade analyses and assessments supporting MOSA should be completed and MOSA-enabled system elements specified, before contracts are let for technology development of those system elements. Successful implementation of MOSA approaches requires the synchronized acquisition of data rights for modular open systems and interfacing architecture elements. These data rights are initially structured to support acquisition of modular open system designs but also should address life-cycle support.
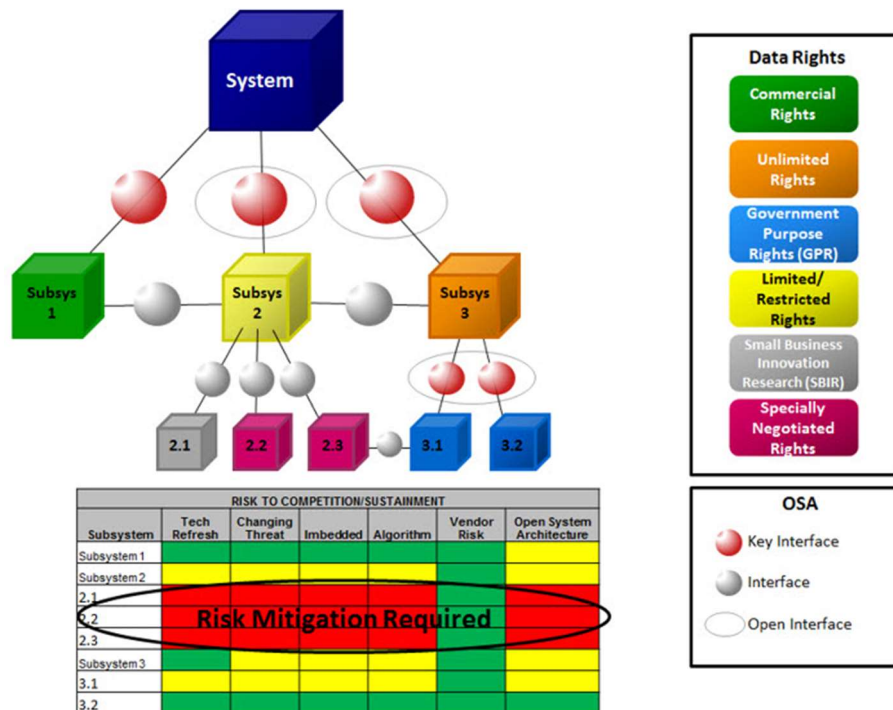
The Figure above depicts an example architectural approach for mapping and assessing which system element interfaces can be open, how associated risk is ascertained and how to visualize the impact to interfaces with other system elements. The figure presents a top-level system view of the MOSA characteristics of system elements. Not all interfaces need to be open at any one level of the design, only those that are required to meet anticipated incremental capability updates, changes in threat or technology insertion. A system view such as this includes a record of the data rights that are required to enable the planned MOSA design. The levels of data rights that need to be required for each MOSA-enabled system element are determined in order to assert the requisite contract requirements to obtain them. The data rights strategy ensures that enterprise-level data

rights flow to system elements and that they support the system architecture. Levels of data rights are described in Chapter (CH) 1 and in Appendix 9 of the OSA Contract Guidebook.

Successfully implementing a MOSA strategy results in the identification of required technical data and software deliverables necessary to field and maintain weapon systems and their logistics support. The Acquisition Strategy should be updated throughout the system's life cycle to reflect changes in the MOSA approach resulting from technology and software evolutionary developments. The Systems Engineering Plan (SEP) is also updated to reflect the MOSA-related updates and modifications employed throughout the system and its system elements.

Specific MOSA-related data deliverables that should be considered include:
- Software Development Plans (DI-IPSC-81427)
- Software Development Status Reports (DI-MCCR-80459)
- Software Development Summary Reports (DI-MCCR-80902)
- Software Design Descriptions (DI-IPSC-81435)
- Hardware development plans and Hardware Design Descriptions

In addition, the PM should maintain an OSMP. The plan describes the offeror's approach for:
- OSA, modularity and open design
- Inter-system element dependencies
- Design information documentation
- Technology insertion
- Life-cycle sustainability
- Interface design and management
- Treatment of proprietary or vendor-unique elements
- Reuse of preexisting items, including all commercial-off-the-shelf/non-developmental item (COTS/NDI) system elements, their functionality and proposed function in the system
- Copies of license agreements related to the use of COTS/NDI system elements for government approval

The open system management plan should also include a statement explaining why each COTS/NDI system element was selected for use.

Program products typically used in making decisions regarding MOSA include:
- System Requirements
- Acquisition Strategy (AS)
- Program Protection Plan (PPP)
- Analysis of Alternatives (AoA)
- Enterprise Architecture

Modular Open Systems Approaches and requirements should be addressed at design reviews, e.g., System Requirements Review (SRR), Preliminary Design Review (PDR and Critical Design Review (CDR).

See DoD Acquisition Streamlining and Standardization Information System (ASSIST) homepage for more data item deliverables that may be appropriate for each specific program and DoD 5010.12-M for data deliverables.

10.2 MOSA Modularity Grouping Concept: Technical Analysis

10.2.1 SoS Grouping Concept

Given that MIL-STD 881D provides a general categorization or current taxonomic breakdown of the DoD platforms and systems, it is evident that the tier (Tier 1) above the MIL-STD groupings with likely require an expanded Platform and System "Type" taxonomy to more directly support different focus perhaps more applicable to joint mission planning and Mission Engineering efforts. This paper largely focuses on Group 2 and recommends that the Mil-STD largely be used as a standardized, "product oriented" breakdown of the functionally based components, elements, and parts of DoD systems. This standardization is a necessary step in facilitating standard partitioning and module . identification. Three groups are proposed to clarify what is addressed in this paper and what is left for future work   Group 2 is the focus of this paper, Group 1 should be addressed as part of the Mission Engineering Initiative and Group 3 is the subject of one of this papers recommendation for future work. The groups are addressed in the next three subsections.

10.2.1.1 Group 1 Joint Force or Mission Tier

This is the tier that should address the modular partitions and associated interfaces at the Mission or Joint Force level. (E.g. Platform-to-Platform interface level per the legislation). It can also be thought of as the level above MIL-STD-881D coverage, but utilizing the modules acquired in accordance with the MIL-STD breakdown. This, perhaps, is this level most Applicable to the current DoD to Mission Engineering initiative. Other considerations in this case may be as follows:

- How the Warfighter uses Mechanization or combinations of Machines synergistically to enhance Force capability and Mission effectiveness.

- Mission and Operations Analysis Problem. Planning of Combinations of Ships, Airplanes, Land Vehicles, Personnel, etc. for various Missions (Battle Planners-Wizard Warriors-Mission Engineers)

- Interoperability (technical communication systems, digital systems, and other highly technical considerations as well as human related operations of disparate systems). Platform to platform interfaces should be addressed in this grouping (We recommend that the NDIA Mission Engineering group do this). ***Interfaces, as called out in the legislation, should be addressed covering identification of Interface management authority and responsibility for each identified interface and any associated risks and issues associated with the interface.*** SoS's documentation should identify these interfaces and management responsibility for each.

Group 1 deals with the SoS's and Mission or Enterprise levels. This includes major platform to major platform interfaces and associated mission and enterprise capabilities.

10.2.1.2   Group 2 System Acquisition Tier

This tier should address the modular partitions and associated interfaces called out in the legislation at the Platform and/or Major System Tier. This is the Tier appropriate for MIL-STD-881D[1]. This grouping should address interfaces for major component to major system and major component to platform) (per legislation). Note that platform to platform interfaces should be covered as part of Group 1. It is recommended that MIL-STD-881D be adopted as the SoS's, architecture and system engineering lexicon in addressing models representing system decomposition taxonomy. MOSA objectives and characteristics should then be applied appropriate to the taxonomic level. (E.g. Ship modular sections versus circuit card modules, etc.).

A single acquisition program or system would be classified as Group 2. This would include dealing with its external interfaces as defined by Group 1 and controlling its internal subsystem and component interfaces including major component to major component and major system to platform interfaces. This includes capabilities at the single platform, major system and component Levels.

In defining the Group 2 system acquisition taxonomy within the SoS's, DoD has an existing hierarchal breakdown of the various DoD major systems in MIL-STD-881D. The MIL-STD has a series of Appendixes which provide the decomposition of our major system types into a standard, top level, set of elements and components. The individual project or acquisition command is then charged with producing the lower levels (e.g. NAVSEA ESWBS[1]) of the WBS. Note the upper levels of the WBS will change much slower than the lower levels. Therefore the configuration management authority will change as we go to the lower taxonomic levels. . (E.g. upper levels maintained by OSD in the MIL-STD and lower levels maintained by acquisition or logistics commands). The lowest levels will also show up in the EVM cost reporting of the respective vendors.

The MIL-STD-881D major categories of DoD systems are as follows:

a. Aircraft Systems
b. Electronic/Generic Systems
c. Missile/Ordnance Systems
d. Strategic Missile Systems
e. Sea Systems
f. Space Systems
g. Ground Vehicle Systems

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[1]MIL-STD-881D, 9 April 2018 Work Breakdown Structures for Defense Materiel
1S9040-AA-IDX-010/SWBS 5D Volume 1 and S9040-AA-IDX-020/SWBS 5D Volume 2 - Users Guide for Expanded Ship Work Breakdown Structure (ESWBS) for All Ships and Ship/Combat Systems
(Copies of this document are available from Defense Technical Information Center (DTIC), 8725 John J. Kingman Road, Fort Belvoir, VA 22060-6218.)
(1) OUSD (AT&L) Memo, Standardization of Work Breakdown Structures to Support Acquisition Program Management, 9 Jan 2009

h. Unmanned Maritime Systems
i. Launch Vehicle Systems
j. Information Systems/Defense Business Systems
k. Common Elements

It should be noted that appendix k is common elements. At first glance it appears that this could be a place to bring visibility to common upper level modules (e.g. common displays or work stations. common computing elements, common connectivity elements, etc.). Currently this is not described as the purpose. The purpose is stated as:

> *"This appendix provides the definitions for services elements (i.e., Integration, Assembly, Test and Checkout; Program Management; Systems Engineering; Training; Peculiar Support Equipment; etc.) whether common or unique to the Defense Materiel Items defined in Appendices A-J. All elements that are common and appear in all appendices, are defined in K.3".*

As an initial thought perhaps the MIL-STD should include a section or appendix for common modules. This perhaps should be the topic of future discussions.

From here the System is broken down into the top tier sub elements. An example is shown in Figure 10-1 below.
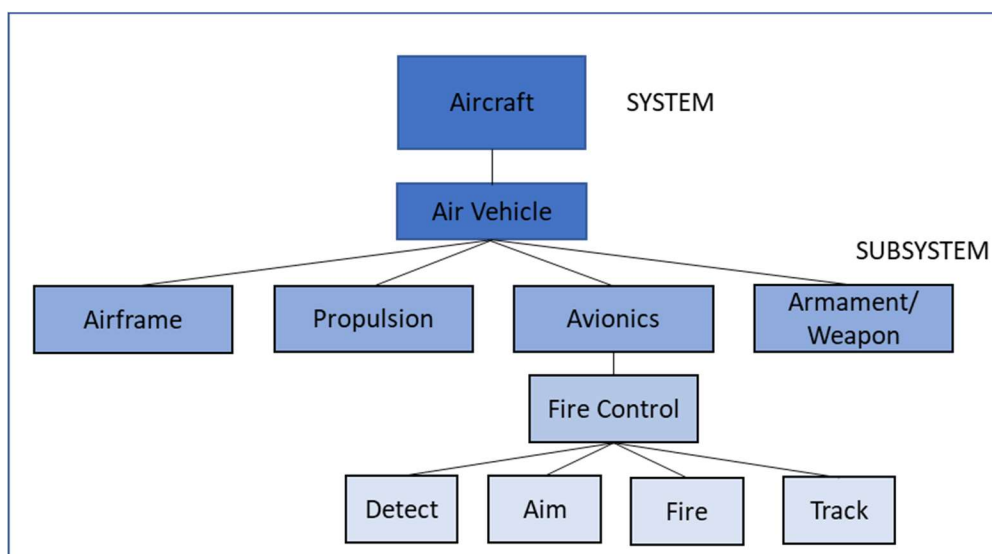
Extracted from MIL-STD-881D (FIGURE III. Identification of major subsystems and functional requirements)
Figure 10-1: Hierarchical Breakdown of System vs Subsystem

[1]S9040-AA-IDX-010/SWBS 5D Volume 1 and S9040-AA-IDX-020/SWBS 5D Volume 2 - Users Guide for Expanded Ship Work Breakdown Structure (ESWBS) for All Ships and Ship/Combat Systems

(Copies of this document are available from Defense Technical Information Center (DTIC), 8725 John J. Kingman Road, Fort Belvoir, VA 22060-6218.)

10.2.1.3   Group 3: Software

Software has unique requirements as far as definition of and management control of interfaces, associated partitioning and modularization (or componentization) as well as other considerations. Software can be thought to exist at all Tiers and levels, from software in a radio's Field Programmable Gate Array (FPGA) to the code and applications in the mission or joint force command and control systems. MIL-STD-881D1 only addresses software as Computer Program Configuration Items (CPCIs) and taxonomy to be defined by the designer. It does however, show them grouped by build which may only loosely be related to MOSA (similar to modular ship construction).   Here it is recommended that lexicons addressing software taxonomy with appropriate MOSA requirements be developed (beyond the scope of this report) **(Recommendation #4)**. Taxonomies such as the Joint Common System Function List (JCSFL), W3C and OSI layered models may assist in this effort.

11. Results of Survey of Industry Needs from OSD

This Appendix contains results from the informal industry survey on the question: "What does Industry need from OSD to show OSD's commitment to MOSA?"

This question was asked by Phil Zimmerman and was assigned to the NDIA Architecture Committee as a MOSWG action item. Results were obtained from 61 members of the NDIA Architecture Committee as well as discussions at the 22 May 2019 Committee meeting.

Q: *What does Industry need from OSD to show OSD's commitment to MOSA*?

A:
1) Release of a MOSA measurement and assessment model developed by independent standards body, and required on all future acquisitions.
2) Acquisition Reference Model and examples of a successful MOSA implementation on programs
    - Contractors are now typically asked to show MOSA compliance in their offerings, but there are no objective standards for them to comply with
    - Supplying exemplar MOSA program implementations will make it more likely that contractors can and will create and offer similar solutions
3) Satisfactory OSD policy and regulations for implementing Technical Data Rights and IP (those impacted by MOSA); this is an important part of the MOSA legislation, yet guidance is lacking for Industry.
4) Premium incentive for successful implementation of MOSA on programs (potentially included in programs' award fee structures)
5) Mandate to acquisition programs that MOSA implementation is not an option, but an absolute requirement in future acquisitions (an all or nothing MOSA implementation requirement for the defense industrial base);

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- Currently MOSA applies only to ACAT-1 programs; a mandate that it applies to all programs would show demonstrate OSD commitment
- The current legislation allows for ACAT-1 acquisition PMs to obtain a waiver from MOSA requirements; contractors can't be sure what percentage of programs will be granted waivers. Waivers need to be eliminated or very tightly controlled.

6) Detailed implementation plans from each of the Services' acquisition offices in response to the Tri-Services Memo on MOSA.

7) Development and release of a detailed, common taxonomy of Open Systems and MOSA implementation terms to establish boundary conditions and partitions, revealing key interfaces.

8) For each program, the procuring government agency provides their MOSA strategy to competing contractors early in the acquisition lifecycle; this will allow contractors to plan their technology investments and business plans accordingly.

9) Consistent DoD-wide definition of government Ownership of the Technical Baseline (OTB), including boundary conditions, establishing acceptable configuration change management processes, and data model implications. Also address the concern of maintaining the integrity of IP delivered to the government after it is delivered.

10) Ensure there are adequate levels of DoD support to enable MOSA-related activities, such as standardization, open architecture reference models, metrics, and interoperability. DoD and the Services provide increased support and touch points to the defense industrial base via engagements in standards bodies, consortiums, working groups, and professional associations

12. OSD Guidance on MOSA

The Office of the Deputy Assistant Secretary of Defense (ODASD) has offered guidance on the MOSA Initiative, including its benefits, program management guidance, as well as its place within DoD policy. The information is accessible at:
https://www.acq.osd.mil/log/MPP/ats_opensystems.html

In this site, the following MOSA guidance is provided:

- Under Secretary of Defense for Acquisition, Technology and Logistics (AT&L) Memo Amplifying DoDD 5000.1 Guidance Regarding Modular Open Systems Approach Implementation

- Instructions for Modular Open Systems Approach Implementation

- New Guidance for Modular Open Systems Approach Implementation

- Background & Historical Information

13. Abbreviations and Acronyms

AHP	Analytical Hierarchy Process
AoA	Analysis of Alternatives
ARM	Acquisition Reference Model
CDRL	Contract Data Requirements List
CAPE	Cost Assessment and Program Evaluation
CONOPS	Concept of Operations
CPCI	Computer Program Configuration Item
DAG	Defense Authorization Guide
DAU	Defense Acquisition University
DID	Data Item Description
DoD	Department of Defense
DoDAF	Department of Defense Architecture Framework
DTIC	Defense Technical Information Center
ESWBS	Expanded Ship Work Breakdown Structure
FPGA	Field Programmable Gate Array
GOTB	Government Ownership of the Technical Baseline
ICD	Interface Control Document
IP	Intellectual Property
MoDAF	United Kingdom Ministry of Defense Architecture Framework
MOSA	Modular Open Systems Approach
MOSWG	Modular Open Systems Working Group
NDIA	National Defense Industrial Association
OSA	Open Systems Architecture
OSD	Office of the Secretary of Defense
OSM	Open Systems Management
OSMP	Open Systems Management Plan
RFP	Request for Proposal

SE	Systems Engineering
SEP	Systems Engineering Plan
SME	Subject Matter Expert
SoS	System of Systems
SOW	Statement of Work
SW	Software
TEMP	Test and Evaluation Master Plan
TRL	Technology Readiness Level
UAF	Unified Architecture Framework
UAFP	Unified Architecture Framework Profile
UPDM	Unified Profile for DoDAF/MoDAF
WBS	Work Breakdown Structure

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