OPEN SYSTEMS POLICIES AND ENFORCEMENT CHALLENGES

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ABSTRACT

The Modular Open Systems approach (MOSA) is both a business and engineering strategy for developing a new system or modernizing an existing one. As a business strategy, the MOSA enables program teams to build, upgrade and support systems more quickly and affordably. This can be achieved through the use of commercial products from multiple sources and leveraging the commercial sector investment in new technology and products. The technical portion of the MOSA addresses a system design that is modular, has well defined interfaces, is designed for change and, to the extent possible, makes use of commonly used industry standards for key interfaces. This system design is best accomplished using collaborative engineering based on sound systems engineering processes. Adherence to MOSA is needed more than ever to develop the single as well as the system of systems needed to maintain the superiority of U.S. military forces within the context of growing asymmetrical threats, unprecedented rate of technological change, and requirements for joint warfighting capabilities. The following article will elaborate on the MOSA concept and furnish readers with a quick reference and better understanding of scope and content of the latest DoD MOSA policies and directions, and the means established to enforce their implementation. The paper will also provide justification for the enactment of such policies and will discuss the requirements and challenges for implementing MOSA in new and legacy systems.

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Purpose: The guidance contained in this paper will assist government Acquisition Program Managers, their staff, and contractors to become more familiar with the DoD Modular Open Systems Approach (MOSA) concept and policies, and better understand the steps needed to more effectively comply with the MOSA policy requirements contained in the DoDD 5000.1 and other DoD directives. To accomplish these goals, the paper will elaborate on the following MOSA related topics:

1. Concept and principles
2. Policies, directives, and guidance
3. Planning and implementation
4. Assessment
5. Future challenges

I. MOSA Concept and Principles

MOSA is an integrated business and technical strategy that employs a modular design and, where appropriate, defines key interfaces using widely supported, consensus-based standards that are published and maintained by a recognized industry standards organization. As a technical strategy, the focus of MOSA is on developing an adaptable architecture that capitalizes on modular design tenets and specifications and standards that are widely used, consensus based, published and maintained by recognized industry standards organizations. This technical strategy will results in alignment of the physical modularity and functional partitioning to facilitate the replacement of specific subsystems and components without impacting others and, thereby, avoiding the need for major system-level redesign upon upgrade. As a business strategy, the focus of MOSA is on leveraging commercially-funded or developed technologies and taking advantage of increased competition. The business strategy also focuses on managing interfaces as opposed to managing the details of the implementation. The combined effect of following a business and a technical strategy is superior systems that are more affordable and can be fielded more quickly.

The MOSA implementation can have a profound effect on the life-cycle cost of a system. Program managers can have access to alternative sources for the key subsystems and components to construct systems. DoD investment early in the life-cycle is reduced since at least some of the required subsystems or components are likely to already be available, or being developed without direct DoD investment. Production sources can be competitively selected from multiple competitors. Moreover, the system design flexibility inherent in open systems and the more widespread availability of conforming commercial products will mitigate potential problems associated with a diminishing defense-dependent manufacturing base. Finally, life-cycle costs are reduced by long-lived, standards based architectures that facilitate upgrades by incremental technology insertion, rather than by large scale system redesign.

Effective MOSA implementation is contingent upon application of sound systems engineering processes, utilization of Integrated Process and Product Team environment, establishment of a MOSA implementation plan, and adherence to five major principles hereinafter referred by MOSA principles (Please see Figure 1). Programs must follow these MOSA implementation requirements and principles to design an adaptable and affordable system and realize all the benefits of open systems. The most important consideration is that open systems should not be implemented blindly. Programs must assess the feasibility of an open systems design from the outset and only develop an open architecture if the benefits of doing so are greater than the costs. In other words, an open systems design strategy is feasible when conclusive capability, cost, and market analyses point to existence of MOSA enabled capabilities and substantial potential for life cycle cost avoidance in the program.

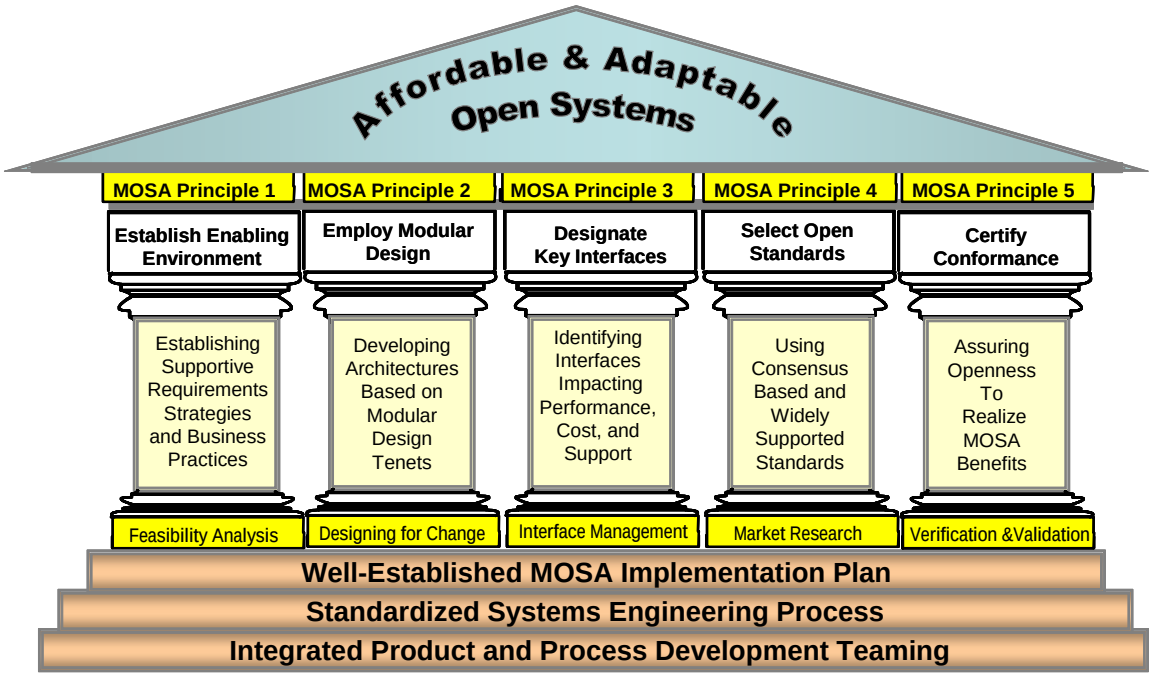

Figure 1: The Modular Open Systems Approach: The Fundamental Building Block of Joint Integrated Warfare Systems

The following paragraphs will briefly discuss each of the five MOSA principles:

- **Principle 1: Establish an enabling environment**

  As soon as the feasibility of an open systems design strategy is proven, the programs must establish enabling business and engineering practices to ensure successful development and implementation of an open architecture for the system. Examples of such practices are accommodating design requirements, and supportive technology development, acquisition, test and evaluation, and

product support strategies. For example, the acquisition strategy should address how programs plan to take advantage of commercial items (state of the art/practice, high reliability, multiple suppliers), capitalize on emerging technology and ensure capability for subsequent technology insertion, control total ownership costs, evolve the system over its lifetime, manage technology cycling and parts obsolescence, and etc. Assigning responsibility for MOSA implementation, ensuring appropriate experience and training on MOSA, continuing market research, and proactive identification and overcoming of barriers or obstacles that can potentially slow down or even, in some cases, undermine effective MOSA implementation are among other supportive practices needed for creating an enabling MOSA environment.

- **Principle 2: Employ modular design tenets**

Modular design is a design where functionality is partitioned into discrete, cohesive, and self-contained units with well-defined interfaces that permit substitution of such units with similar components or products from alternate sources with minimum impact on existing units. To design a system for change, the programs must adhere to four major modular design tenets identified in Figure 2. These tenets determine the degree to which modules are cohesive (contain well-focused and well-defined functionality); encapsulated (hide the internal workings of a module's behavior and its data); self-contained (do not constrain other modules); and highly binded (use broad modular definitions to enable commonality and reuse). By following these tenets, each module will be designed for change and the interface to each module is defined in such a way as to reveal as little as possible about its inner workings which facilitate the standardization of modular interfaces.

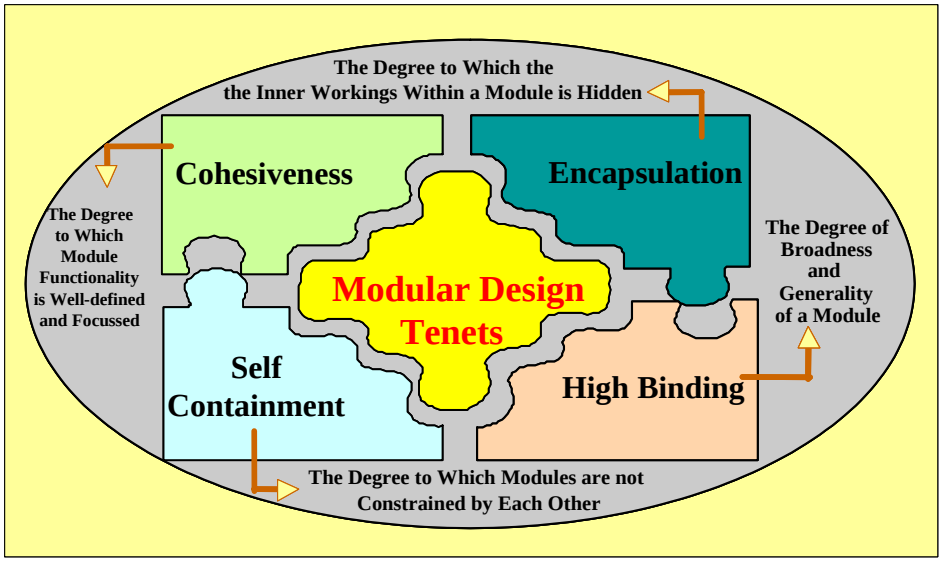

Figure 2: Modular Design Tenets

- **Principle 3: Designate key interfaces**

  To effectively manage and control interfaces, programs need to group interfaces into key and non-key interfaces. Key interfaces should be identified and put under control early in the system acquisition life cycle. Key interfaces are defined as common boundaries shared between system modules that provide access to critical data, information, materiel, or services, or are of high interest due to rapid technological change, a high rate of failure, or costliness of connected modules. For example if the technology turnover is rapid or the design risk is high on one or more sides of an interface, such an interface is designated a key interface subject to rigorous management and control and open standard implementation.

- **Principle 4: Use open standards**

  Programs should establish an on-going market research and analysis activity to identify and track technology and market trends for open (widely supported and consensus-based) interface standards and specific commercial and or non-developmental products (hardware and software, tools and models) that are compliant with such standards for possible use in the system. They need to evaluate potential standards to determine if they support capability requirements and meet open systems objectives for affordable system evolution. Programs should also ensure that the selected standards provide access to non-developmental items and commercial items that are available from multiple sources, and assess the effects of new technology to determine likely evolutions of standards. If emerging standards are used, they should consider participating in appropriate standards bodies to ensure standards definitions meet their program's requirements.

  As part of this principle, the preferences should be always given to the use of open interface standards first, then de facto interface standards, and finally government and proprietary interface standards. Selection of commercial specifications and standards shall be based on:

  - the degree to which the standard is used in the commercial market place, and whether the standard is developed and adopted by consensus based standards bodies or is regarded as proprietary (please see Figure 3);
  - extensive market research that evaluates the short and long term availability of products using such standards;
  - a disciplined systems engineering process that examines long-term tradeoffs between costs and performance;
  - supportability and upgrade potential within defined cost constraint; and
  - allowance for continued access to technological innovation supported by many customers and a broad industrial base.

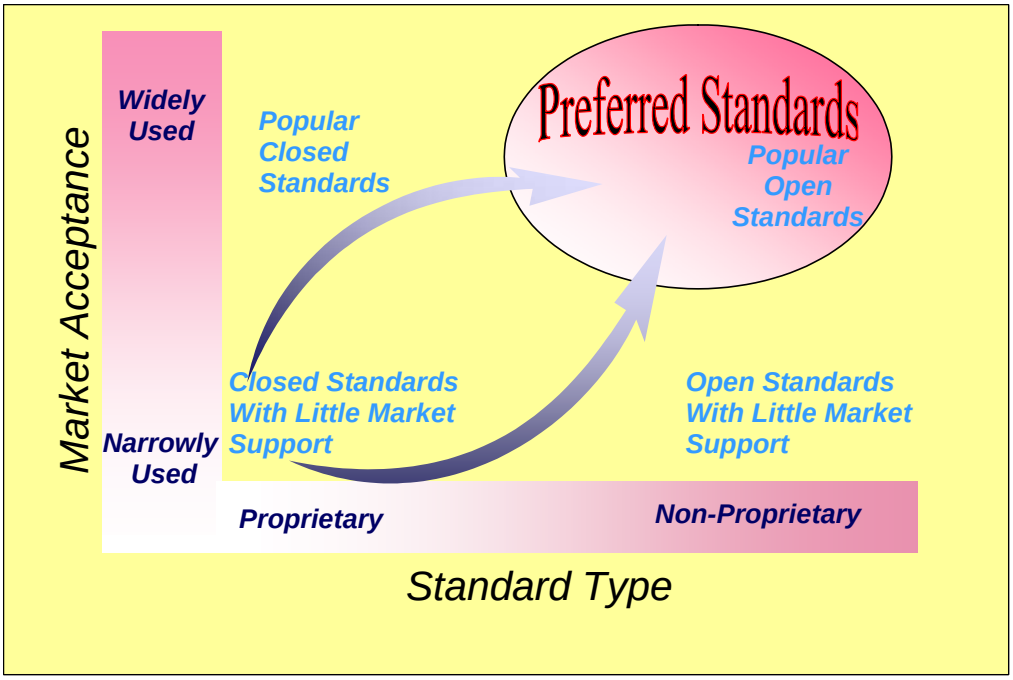

Figure 3: Preferred Standards

- **Principle 5: Certify conformance to selected standards**

  Programs should devise testing plans to ensure conformance of selected commercial items and non-developmental items to appropriate interface definitions especially open standards. They also need to plan for compatibility testing to ensure that system modules interface and function together properly. The ultimate test is the verification that the conformant modules from different suppliers will work properly in the system. Programs should address verification of the profiles to assure they fully meet requirements including sensitivity and "out-of-the-envelope" concerns. Questions to ask in selecting standards and ensuring conformance include the following:

  a. Are the standards based on mature technology and are they currently used in production?
  b. Are there current products available, built to this standard? Are several vendors complying (fully) with this standard?
  c. Does the standard have a defined test suite or conformance criteria to eliminate the time and cost of testing?
  d. Is the standard produced and maintained by a reputable group, whether or not the group is accredited?

II. MOSA Policies, Directives, and Guidance

A. Open Systems policy and Directives

Open systems policies came into existence with the emergent of the Open Systems Joint Task Force as the main DoD advocate for open systems implementation in 1995. The path of enactment and adoption of such policies have mostly been evolutionary. As a result of streamlining process followed in 2002, the open systems policies, similar to other policies, were drastically condensed and in May 2003 reduced into a single phrase under a short paragraph on systems engineering. This paragraph (please see section E1.27 of the DoDD 5000.1) states that, "A modular, open systems approach shall be employed, where feasible." Although the MOSA policy does not have its own paragraph and consists of only a few words, but it delivers a very powerful message to all DoD programs that the DoD leadership is serious about MOSA implementation and wants all the DoD programs to employ MOSA.

The DoD policy stated in the DoDD 5000.1 was then amplified and expanded by a new directive dated April 4, 2004 and signed by the Acting Under Secretary of Defense for Acquisition, Technology, and Logistics. The new Directive commonly referred by MOSA Implementation Memo states that, "The purpose of this memorandum is to amplify and expand the policy for implementation of MOSA as set forth in DoDD 5000.1, dated May 12, 2003. Paragraph E27." It further states that "Commencing October 1, 2004, all programs subject to milestone review shall brief their program's MOSA implementation status to the Milestone Decision Authority (MDA) to determine compliance. Programs not complying with MOSA implementation guidelines shall provide justification or a migration plan to the MDA for achieving compliance. This policy will be included in the next revision of DoDI 5000.2." The memo also states that, "The Open Systems Joint Task Force (OSJTF) is my lead for MOSA and has developed a Program Manager's Guide that provides principles and guidelines for implementing MOSA in new and current programs. In addition, OSJTF has adapted the Office of Management and Budget (OMB) Program Assessment and Rating Tool (PART) in assessing MOSA implementation. Each program will present the results of their PART assessment using the results generated by the tool, at all their major milestone and program reviews. The guide and the PART are available at http://www.acq.osd.mil/osjtf/html/mosa_assessment.html."

On 7 July 2004, the Director of Defense Systems signed a memo that describes how the requirements stipulated within the USD (AT&L) Directive should be addressed for systems and systems-of-systems in the formal acquisition process. Based on the instructions contained in the memo, all DoD acquisition programs should address Modular Open Systems Approach (MOSA) early in their program and acquisition planning, and should discuss MOSA implementation in the context of their overall Acquisition Strategy and to the extent feasible in the Technology Development Strategy. MOSA implementation issues should be identified and addressed via the IPT process and presented as issues to the MDA only when unresolved at a lower level. This memo also made the OSJTF responsible for the development and oversight of MOSA policy to

include emerging system-of-systems policy to develop open integrated architectures for capability areas. Figure 4 summarizes the main thrusts of the current DoD open systems policy and directives.

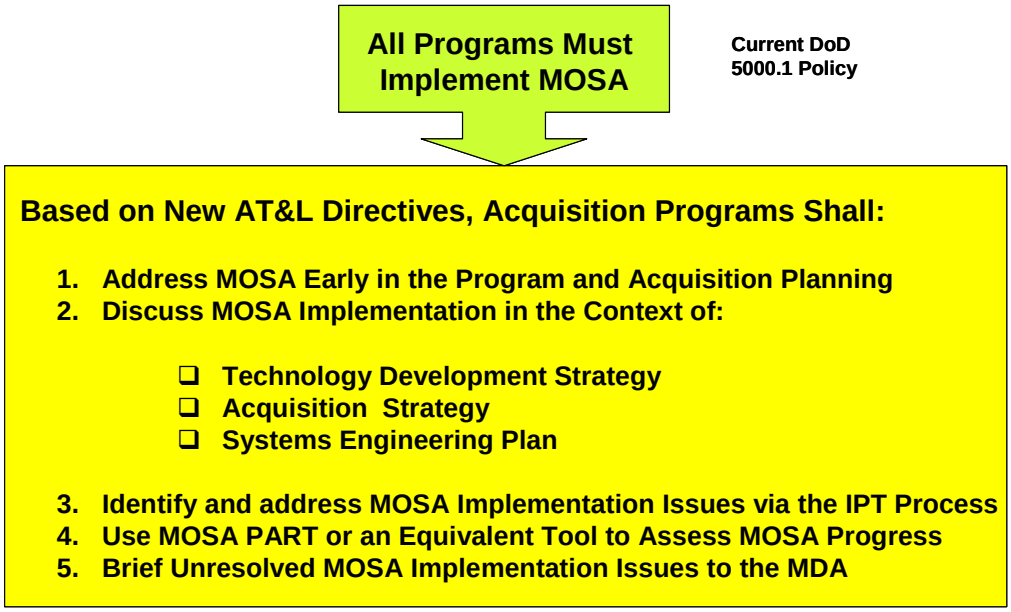

Figure 4: DoD Open Systems Policy and Directives

B. Open Systems Guidance

The guidance for open systems implementation is contained in various chapters of the recently developed DoD Acquisition Guidebook, and in a detailed guide prepared by the OSJTF called "A Modular Open Systems Approach (MOSA) To Weapon System Acquisition." The OSJTF has worked closely with the Defense Acquisition Policy Working Group and has placed top level guidance in various chapters of DoD Acquisition Guidebook. The main MOSA guidance is presented at Chapter 2, Defense Acquisition Program Goals and Strategy; Chapter 4, Systems Engineering and Integrated System Design; and in chapter 5, Life-Cycle Logistics. As a result of this top level implementation guidance, the MOSA is now a principal element of the Acquisition Strategy and an integral part of the Systems Engineering Plan of every program.

The detailed guide prepared by the OSJTF (i.e., Program Manager's Guide) provides program managers, system engineers, contracting officers, and the entire program team the steps and tools needed to effectively plan the MOSA implementation. This guide enables new and current (legacy) programs to realize the DoD vision of making MOSA an integral part of every acquisition strategy to achieve affordable, evolutionary, joint combat capability. To review and download the OSJTF PM Guide, please go to http://www.acq.osd.mil/osjtf/implement/implement_tools.html

III. MOSA Planning and Implementation

Program offices should plan for MOSA implementation with specific actions and development milestones. MOSA planning should address how MOSA fits into a program's overall acquisition process; identify the actions that a program will take to analyze, develop, and implement a system or a system-of-systems architecture based on MOSA principles; and establish the criteria, tools, and measures to monitor and assess program progress in implementing MOSA. The best approach to follow is to establish a MOSA implementation plan. Such a plan is a roadmap with specific objectives, tasks, principles, and milestones for putting MOSA into practice. The MOSA implementation plan should, at a minimum address the following five major tasks:

- Identify and analyze capabilities and strategies that could most effectively be pursued by open system design solutions.
- Assess the feasibility of open systems design solutions
- Establish performance measures to assess MOSA implementation progress
- Use MOSA principles to develop an open architecture
- Establish a procedure to identify and resolve MOSA implementation issues and report the unresolved issues to Milestone Decision Authority.

In terms of open systems, the acquisition strategy should address how the program will benefit from MOSA to minimize the time and cost required to satisfy approved capability needs, and maximize affordability throughout the program life cycle. An open systems-based acquisition strategy should address how a program intends to capitalize on MOSA principles to:

a. determine how the program should be divided into technology spirals and development increments, and how early increments will be integrated or retrofitted with subsequent increments in the most cost effective manner,

b. integrate a system with other systems in a joint integrated architecture venue,

c. achieve net-centricity and interoperability

d. take advantage of commercial items (state of the art/practice, high reliability, multiple suppliers),

e. gain access to the latest technologies from competitive sources of supply throughout the system life cycle to ensure capability for subsequent technology insertion,

f. control total ownership cost and reduce the development cycle time, and

g. manage technology cycling and parts obsolescence.

As part of the MOSA implementation plan, the programs may establish open systems objectives and formulate strategies to achieve these objectives. Following are examples of areas within which open system objectives are recommended:

- Lifecycle Management and Technology Insertion. The objective is to ensure affordable modernization throughout the systems life cycle.

- Supportability: Continued access to multiple sources of supplies. The objective is to reduce risks associated with relying on a single source and higher supportability costs.
- Interoperability. The objective is to ensure the resulting system will be fully interoperable with all of the systems it must interface.
- Integrability. The objective is to ensure the system will provide the warfighters the ability to quickly interconnect and assemble existing forces, systems, subsystems, and components in order to construct new ones in a synergistic and affordable way.
- Adaptability. The objective is a system design sufficiently robust to enable effective adjustment to changes in threats and technology.

The PM should make a business case for using open system architectures. The program management office should preferably use a dynamic business case analysis model and apply market research findings to evaluate the appropriateness and feasibility of open systems. The model should consider changes in technology and threats to evaluate the total life cycle costs of designing the system as an open rather than a closed system. The MOSA implementation process should also describe how the program will use market research throughout the life of the system to identify emerging standards and compliant products, and new technologies to support future technology insertion. The review of technologies and standards should assist the PM in the identification of developmental risk areas with consequent impact on test and evaluation efforts. The PM should also conduct market research as part of the systems development efforts to assess the availability of open standards to insure that interfaces developed permit exploitation of commercial and military markets.

To implement open systems the users must identify the lowest level (e.g., system, subsystem or component) at and above which they define key interfaces and require conformance of these interfaces to open standards. Also, the users should anticipate how this level may change over time and assess the impact of a given-level of openness (i.e., key interface control level) on long-term viability and affordability of the system. If proper level(s) of openness is selected and the hardware and software is effectively partitioned, processing hardware can be replaced with new technology without modifying application software. Additionally, application software can be modified without necessitating hardware changes.

The open system architecture should be addressed early in a program to maximize the number of potential solutions, and thereby help reduce program cost and risk. By focusing on an open architecture early in a program, the specific technology used in its implementation can then be chosen as late as possible. Moreover, the interfaces used within an open system architecture must be managed more rigorously than in a closed architecture. An interface specification or standard is inherently a performance standard, is used as such by industry, and must be recognized as such in a DoD program. System partitions must not violate the interface, unilaterally extend it, or define it so that it is no longer compliant with the standard. At the start of production, the open systems requirements are published, thus identifying the market opportunities for suppliers.

The application of MOSA in current (legacy) systems is similar to its application to new systems but it is less obvious. Legacy systems usually have operational and design limitations such as size, space, power, and cooling constraints. For these systems, the MOSA principles can provide form-fit-function interface (F3I) solutions within existing packaging, power, and

environmental constraints. In such cases, the open systems solution frequently requires less system resources by using newer, more efficient technologies. The open systems design approach is similar to F3I except that it emphasizes choosing interfaces that are broadly accepted in the marketplace to allow for as many suppliers as possible over the long term.

IV. MOSA Implementation Assessment

Program offices should use assessment tools and specific metrics to gauge MOSA implementation progress, and relate MOSA benefits to program results and objectives. The assessment tools and metrics should use the MOSA principles to identify a set of indicators to appraise MOSA maturity and assess implementation progress. The AT&L Office of Defense Systems adapted the MOSA Program Assessment and Review Tool (PART) from the Office of Management and Budget (OMB) Program Assessment Rating Tool. The OMB PART is a questionnaire designed to provide a consistent approach to rating programs across the Federal government. The OSJTF has tailored this tool to assess the implementation of MOSA throughout the life-cycle of acquisition programs. The MOSA PART is an analytic tool that evaluates responses to a set of interrelated questions to provide acquisition program executives with an objective and evidence-based assessment of the degree that MOSA is implemented in a program. The degree that MOSA is implemented is measured by responses to five sets of questions related to the MOSA principled identified earlier. Based on responses and evidence submitted, a program's MOSA implementation may be rated as exemplary, satisfactory, marginal, or dissatisfactory. To review and download the MOSA PART, please go to http://www.acq.osd.mil/osjtf/

Programs should proactively identify the problems, obstacles and issues they encounter in implementing their MOSA. They can use either the MOSA PART, or other tools to discover potential problems, obstacles, or barriers toward MOSA implementation. For example, the assessment finding may point to the fact that the program does not use an open standard for a key system interface. The program may justify the use of a proprietary standard for the interface based on a market research finding. Such finding may point to the fact that the emerging open standard for that key interface is not yet matured, or the test suits for its conformance testing is not yet available. Under this circumstance, the program will use a de-facto or proprietary standard for that interface but, it should at the same time develop a migration plan to replace the de-facto or proprietary standard with an open one when it becomes available.

The programs should undertake the following procedure to effectively deal with a major MOSA implementation issue (problem, obstacle, or barrier):

1) Use appropriate means to discover MOSA implementation problems, obstacles, and barriers.
2) Analyze and document the problems, obstacles, or barriers, and the circumstances surrounding them.
3) Address the identified problems, obstacles, or barriers via the Integrated Product Team (IPT) process and focus on resolving them at the lower IPT levels. For example, propose a migration plan to attain future openness.

4) Present the identified problems, obstacles, or barriers as issues to the MDA only when unresolved at a lower level. The issues must be reported to the MDA in the context of a summary within the program acquisition strategy. The summary should describe the potential economic impact of the issue (e.g., using closed interfaces) on total ownership costs and the risk to technology maturation and insertion over the service life of the system. The summary should also describe the potential impacts of the issue on the ability to integrate and/or retrofit earlier increments with later increments, and the effects on integrating the system with other systems within a system of systems context.

V. MOSA Implementation Challenges

Generally speaking, the PM may face three types of challenges that can potentially slow down or undermine effective MOSA implementation: barriers and obstacles; future uncertainty; and opportunity costs. These challenges are explained in greater details in the following paragraphs.

Barriers and Obstacles. MOSA implementation barriers and obstacles may be created internally or by outside entities. The PM should formulate strategies to identify and remove or bypass such barriers. The PM should advocate MOSA implementation at the highest levels, and devise plans to reward success and capture and promulgate lessons learned. The PM should also periodically reassess the MOSA implementation challenges to ensure that emerging issues are resolved satisfactorily and the system being developed stay "open."

Let us examine a specific example. Suppose MOSA skeptics argue that MOSA requirements are not part of the capability documents and are not worth the associated effort or money. In addition to fundamental policy to the contrary, the PM should work closely with the Joint Staff to ensure that the capability documents contain language requiring continued viability and openness, periodic technology refreshment, and continued access to multiple sources of supply throughout the entire life cycle of the system.

Future Uncertainty. The key to achieving the benefits of MOSA lies in making open systems an integral part of not only the systems engineering process but also long-term sustainment. With a commitment to MOSA, systems engineers today and tomorrow can tap into a broad wealth of technologies from many sources. On the other hand, building unique systems with custom standards eliminates the substantial engineering and business advantages available in the commercial marketplace. It will likely diminish design flexibility and raise costs, and could negatively affect schedule and performance.

The PM may also face the uncertainty of immature or inappropriate open standards. The PM should understand the standards development and certification process, and plan to maintain consistent and constructive participation in the deliberations of the industrial standards organizations.

Opportunity Cost. The PM should recognize that the commitment to open standards imposes constraints and requires discipline (as does any *approach*). For example, if the integrity of the interfaces is not maintained, or if extensions found on limited product lines are used in the

design, then the system design may cease to be open, benefits of openness could be lost, and the design could become more like a traditional point solution than an open systems solution.

Conclusion

In light of asymmetrical and evolving threats and rapidly changing technologies, the DoD can no longer afford long development cycle time and high cost of ownership of systems that are acquired as an end to themselves. The age of acquiring and developing stove-piped systems is over and the indications point to a paradigm shift characterized by joint integrated warfare which is enabled by net-centric, integrated, and open architectures. To realize the benefits of open systems, programs must follow a MOSA.

MOSA capitalizes on best engineering and business practices to leverage the investments made in commercial products, practices, and technologies by the private sector to field superior warfighting capability more quickly and more affordably. The commercial sector innovations and new technology investments are most effectively leveraged when programs or projects (1) choose commercially supported specifications and standards for selected system interfaces (external, internal, functional, and physical), products, practices, and tools, and (2) build systems based on modular hardware and software design tenets.