REPORT OF THE

DEFENSE SCIENCE BOARD TASK FORCE

ON

OPEN SYSTEMS

October 1998

OFFICE OF THE UNDER SECRETARY OF DEFENSE
FOR ACQUISITION AND TECHNOLOGY
WASHINGTON, D.C. 20301-3140

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DEFENSE SCIENCE
BOARD

OCT 5 1998

MEMORANDUM FOR UNDER SECRETARY OF DEFENSE (ACQUISITION AND TECHNOLOGY)

SUBJECT: Report of the 1998 Defense Science Board (DSB) Task Force on Open Systems

I am pleased to forward the final report of the 1998 DSB Task Force on Open Systems (OSTF). This effort, chaired by Dr. Wayne L. O'Hern, Jr., was formed to examine the benefits of, criteria for, and obstacles to the application of an Open Systems approach to weapon systems, and to make recommendations on revisions to DoD policy, practice, or investment strategies that are required to obtain maximum benefit from adopting Open Systems.

It has been apparent from the onset of the study that an OS mindset was an essential core value which applied broadly across the DoD and not just to the engineering of weapons systems. Already, there have been a number of programs which have leveraged Open Systems concepts and reaped enormous benefits. However, despite the pockets of good work and salient successes within DoD, the Task Force has concluded that the Department lacks a unifying concept and a solid foundation from which to rally around. As a result, the Task Force believes that there is little hope of achieving many of the DoD's key objectives without a massive infusion of an Open Systems Process (OS Process) into its affairs.

The challenges facing DoD are enormous, but so are the benefits. It is the hope of the OSTF that DoD leadership aggressively embrace an OS Process and force the necessary cultural change.

I endorse all of the Task Force's recommendations and propose you review the Task Force Chairman's letter and report.

Craig I. Fields
Chairman

OFFICE OF THE SECRETARY OF DEFENSE
3140 DEFENSE PENTAGON
WASHINGTON, DC 20301-3140

DEFENSE SCIENCE BOARD

30 September 1998

Dr. Craig I. Fields
Chairman DSB, OUSD(A&T)
3140 Defense Pentagon, Room 3D965
Washington, DC 20301-3140

Dear Dr. Fields:

Attached is the final report of the DSB Task Force on Open Systems. The Task Force was formed to examine the benefits of, criteria for, and obstacles to the application of an Open Systems approach to weapon systems, and to make recommendations on revisions to DoD policy, practice, or investment strategies that are required to obtain maximum benefit from adopting Open Systems.

The Open Systems Task Force (OSTF) found this to be a challenging assignment. There already existed an OSD Joint Task Force (OS-JTF) which has done marvelous work introducing the commercial Open Systems (OS) experience to DoD. There have been a number of programs which have leveraged OS concepts and returned enormous benefits. Examples are the Army Intelligence and Electronic Warfare Common Sensor program, Navy submarine combat control systems, and coordinated DARPA, Air Force, Navy, and Marine programs for a common processing upgrade for F-15, F-18, and Harrier.

So what could be the value-added of this DSB OSTF? In initial discussions with Dr. Jacques Gansler, the USD(A&T), and Mr. Leonard Burke, Director of the OSD OS-JTF, each cited the pockets of good work and salient successes but lamented the general state across DoD. They emphasized the need for a unifying concept, a solid foundation which DoD could rally around. This became the primary objective of the OSTF.

As the OSTF identified the core principles of OS, it quickly became apparent that an OS mindset is an essential core value which applies broadly across the Department, not just to the engineering of weapons systems. We reviewed a number of DoD objectives, ranging from evolving concepts of warfare as envisioned in Joint Vision 2010 and the Service equivalents, to Mr. Cohen's Defense Reform Initiative, to Acquisition Reform -- all to be achieved in an era of budget distress. We were struck by the dependence of these priorities on the attributes provided by an OS approach – so much so that the OSTF concludes there is little hope that such priorities can be achieved without a massive infusion of an Open Systems Process (OS Process) into the affairs of the Department. We argue that an OS Process is a cornerstone of the solutions that will be needed to meet our current and future challenges.

DoD and its industrial partners have extensive competencies and an effective OS Process is well within grasp. Ironically, however, it is the opinion of most interviewees that success is highly unlikely. DoD and higher level oversight processes and cultures are dysfunctional from an OS perspective, and are so entrenched that fundamental change is thought to be almost impossible. Implementing a strong OS Process within DoD is primarily and institutional matter.

The challenges facing DoD are enormous. Fortunately, so are the demonstrated operational, functional, and economic benefits of OS attributes. With a need so great and significant relief so close at hand, it is the hope of the OSTF that DoD leadership aggressively will embrace an OS Process and force the necessary cultural change.

Many people made significant contributions to this effort. I have tried to acknowledge many of them in the Foreword to this Report. Hopefully they find their hard work and expertise reflected in the attached Report, which I believe provides the Department with a thoughtful approach for addressing a very important issue.

Sincerely,

SIGNED

Wayne L. O'Hern, Jr., Ph.D.
Chairman, DSB Task Force on Open Systems

attch: "An Open Systems Process for DoD"

Defense Science Board

Open Systems Task Force

An
Open Systems Process
For DoD

Task Force Chairman - Dr. Wayne L. O'Hern, Jr.

FINAL REPORT
25 SEPTEMBER 1998

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FOREWORD

Many people and organizations have been generous in assisting the DSB Task Force on Open Systems (OSTF). Mr. Peter Marino started as Co-Chair of the OSTF before being asked to co-chair another effort. His direction, insights, and support were of great value. Many members of the Defense Science Board, including Dr. Craig Fields, Dr. John Foster, Gen. Larry Welch, USAF (Ret), Dr. George Heilmeier, the Honorable Anita Jones, VADM Jerry Tuttle, USN(Ret), Dr. Robert Cooper, Mr. William Howard, Jr., and Dr. Michael Frankel contributed significantly to our efforts. Mr. John Ello, Maj. Wynne Waldron and Maj. Tony Yang of the DSB staff also have been very helpful. The OSD Open Systems Joint Task Force (OS-JTF) has been behind us all along -- I wish particularly to commend the contributions of Mr. Leonard Burke and Dr. Chien Huo. Similarly, we received extensive support from other government activities, particularly Program Offices and Depots which very much need the benefits of an Open Systems Process. Industry provided a plethora of information, and in many instances are struggling to infuse Open Systems approaches within DoD constraints. Lastly, I wish to thank to the members of the OSTF, listed in the Report and in Appendix B, who put so much into this in the hope that DoD really can change when it is important.

Wayne L. O'Hern, Jr., Ph.D.
Chairman
DSB Task Force on Open Systems

EXECUTIVE SUMMARY

Open Systems - The Commercial Experience

We know from our computing, telecommunications, electronic entertainment, and local building codes the power of smart modularity. Open "Plug & Play" architectures (computers, a well-wired home, stereo systems) permit us to configure, reconfigure and update hardware and software from a wide range of general purpose and specialty suppliers. Wide interchangeability permits niche products to address many diverse user communities, creating a large aggregate market and fueling massive private investment, enabling a plethora of Commercial Off The Shelf (COTS) products at previously unimagined low costs. In parallel, a new networking industry has sprung up, enabling broad interoperability between hosts which are not otherwise necessarily compatible. Thus our economy and culture has been revolutionized within a couple short decades and our institutions and citizens have achieved a quantum leap in operations, competitiveness, and effectiveness.

The commercial revolution has been built upon the concept of extensive modularity, driven by carefully crafted architectures implemented at various tiers throughout the product chain. Architectural concepts are very different at the several levels in the product hierarchy. Suppliers strive to achieve "Plug & Play" interchangeability within their product architectures so that users can configure and upgrade the overall system with components (monitors, speakers, tires, etc.) from many sources according to individual needs. The effectiveness of "Commercial Plug & Play" varies. For instance, Apple is relatively narrowly supported but has good interchangeability within their architecture, while Microsoft is more widely supported but generally does not work as well. Achieving the desired degree of Plug & Play requires careful management and engineering attention.

Left to their own devices, networking the Apple and Microsoft lines would still be relatively awkward. A whole new industry has emerged to provide broad connectivity. Diverse user products can now be connected relatively seamlessly through the Internet and new wideband telecommunication architectures. We note that the platform suppliers generally did not and probably could not supply revolutionary connectivity -- that came from outside initiatives. Further, true interoperability at the platform level, which our OSTF refers to as "Plug & Fight," *does not* derive just from good connectivity, for protocols and applications inside the platforms also have to be compatible. Not only must our computers talk to each other, but, for example, my MS Word program must accept your Word Perfect document. Thus, Plug & Fight can not be achieved just by providing good Plug & Play platform architectures. There needs to be higher order mechanisms for effective interoperability to be achieved.

And finally, none of all of this would be economically feasible without the massive economies offered by lower tier COTS components — microprocessors, video cards, network servers, etc. It is not conceivable that individual commercial user communities could have funded unique component developments for their individual needs. It is only through massive reuse of commercial investment across many applications that the revolution has been possible.

Application to DoD

There are important parallels for DoD. Indeed, the OSTF has found that many commercial OS principles and practices have direct application in military systems and that great benefits would accrue. But OS are not just Best Business Practice. We note that the new operational concepts expressed in *Joint Vision 2010* (JV2010) and the Service equivalents envision ad hoc, composite forces quickly constituted and deployed to distant lands, requiring extensive interoperability corresponding planning, training, transport, and sustainment-- true force-level "Plug-&-Fight." To support this operational concept, Forces and combat support systems must be modular, interchangeable, and interoperable. Gen. Larry Welch observed that the ability to readily integrate force elements as needed at the moment is usually more important than the final increment of individual performance.

We also note Defense Reform Initiative objectives of OSD and USD(A&T) such as reducing ownership costs and acquisition timelines and dealing with rapid technological obsolescence -- all to be accomplished in a severe budget environment that may further worsen. Extensive modularity, driven by commercially oriented OS Process architectures, will be required to achieve such affordability and efficiencies.

In fact, the OSTF argues that major DoD priorities *cannot be achieved* without a massive infusion of OS attributes through an organized OS Process. Some sort of OS Process must become a DoD *mindset* and *core competency*.

The required infusion of an OS Process must manifest in three important ways:

- Continuous Viability. Forces, systems, and processes (ex. logistics management systems) must be configured to economically maintain operational, technical, and sustainment viability throughout the life of the program. Most legacy stovepipe solutions are not viable in today's world and jeopardize missions, programs, and budgets.
- Architecture-Driven Modularity. It is clear that DoD must be very modular at the Force, system, and process levels. It is essential that modularity be driven by smart architectures tailored at each level of the product chain, from the Force level (ex. for interoperability) through intermediate levels to systems and on down to individual supplier components. The architectural hierarchy itself must be carefully crafted or the simultaneous achievement of Plug & Fight, Plug & Play, and COTS economies will be lost.
- Manage to the Natural Cycle Rates of the Underlying Components. Classic DoD program management and oversight processes baseline designs down to the piece part level -- and then fiercely resist change to the baseline. In an era of rapid product evolution and obsolescence, this approach is dysfunctional. Without refresh, product currency cannot be maintained through the period typically needed for Engineering and Manufacturing Development (EMD), much less through the time needed for test, production, fielding, and sustainment. Rather than trying to resist change, DoD management processes must proactively enable the various natural change rates of the underlying components. This is a systemic change to DoD acquisition philosophy and will require a major, orchestrated revamping of system management and oversight processes.

Achieving a competent OS Process ought to be straightforward for DoD. The tenants are a variation upon the principles of good system engineering and are within our grasp. It is primarily the institutions and culture which need to change, and such change will be very difficult.

An OS Process for DoD

The OSTF has described an OS Process tailored to DoD needs. Because the field of Information Technology is maturing the understanding of Open System processes, and because most people have personal experience in this area regardless of their individual professional pursuits, this report will tend to use IT examples in examining the axioms of an OS Process for DoD. But the urgent need for and benefits of the OS Process described here apply to almost all forms of electronics, both digital and analog, and most other disciplines such as mechanical, hydraulic, and pneumatic.

The OSP is based upon a hierarchy of architectures to capture the three basic Open Systems attributes — Plug & Fight, Plug & Play, and ready use of COTS.

Hierarchy of Architectures. In the commercial example, Plug & Fight is represented by industry architectures such as ATM for telecommunications and the Internet and Web for networking. Establishing Plug & Fight interoperability is a challenge distinct from achieving Plug & Play systems and can only be achieved by a high order mechanism to force architectures and standards which are truly compatible. For example, both Apple and MS Windows can claim to enable Plug & Play within their own architectures, but cannot by themselves provide rich interoperability -- that comes from the telecommunications and networking industries, the Plug & Fight levels.

Various DoD systems claim to be interoperable because they use widely accepted connectivity standards. But they use *different* connectivity standards which are not fully compatible, and interpret common standards differently; hence, the systems are not truly fully interoperable. To achieve true interoperability across the forces, OSD and JCS must impose and rigidly enforce a single set of mutually compatible and implemented standards, without compromise, in each domain such as C4ISR and logistics management systems.

In the OSTF's architectural hierarchy example, OSD and JCS impose mandatory architectures at the highest level to assure interoperability across the Forces in each relevant domain, such as logistics management, mission planning, etc.

A second level tier would enable DoD-wide system-of-systems requirements such as Cruise Missile Defense or a Single Integrated Air Picture. Similarly, at the next lower tier PEOs may impose architectures for cross-system needs such as commonality -- e.g. common electronic board formats in combat vehicles.

At the platform system level the system architecture is still controlled by the Systems Program Office through the traditional and well-proven Configuration Control Board (CCB). The Program Office objective is to be compliant with higher tier Plug & Fight requirements, to enable Plug & Play throughout the system, and capture the benefits of commercial components. Open components are accommodated by configuring the system to include a carefully orchestrated set of Form, Fit, Function, and Interface (F^3I) "sockets." The F^3I approach permits the overall structure of the system to be controlled without specifying the detailed configuration at the assembly and component levels.

This is the major change: the Program Office enables Plug & Play by ceding control of the detailed configuration to the prime contractor and suppliers. Contractor and supplier control of the detailed configuration is absolutely necessary to capture the economic advantages of COTS, enable technology refresh, and deal with parts obsolescence and a diminishing supplier base. Without this attribute, DoD systems will continue to suffer nearly insurmountable affordability and supportability problems.

Administering the Architectures. The example OS Process outlined in this Report relies upon the existing line management structure, augmented at each tier by advisory Architectural Control Boards (ACBs) patterned after the proven CCB process used by Systems Program Offices. Line Authority establishes requirements and performance based expectations -- the "why" -- while lower echelons develop the "how." As with the Program Office CCB, the ACB acts as a control point advising the Line Authority on compliance before all milestone reviews and key decisions.

An ACB would be established at each organizational echelon having responsibility for an architecture in the hierarchy. This would be an additional role for the OSD/JCS ACC and the Program Office CCB.

Partitioning for modularity is already largely understood from the system engineering process necessary for system and complex software development. Like large software builds, OS will be unforgiving of poor architectures and partitioning. Similarly, interface standards must be chosen carefully. While Openness is always desired, wide use is the more important attribute. Thus the OSTF recommends DoD pursue "Practical Open" solutions.

Risks of Open Approaches. There are of course risks to adopting OS approaches. In return for the enormous economic and schedule advantages of Open standards, DoD cedes some significant degree of control to others. DoD needs to be proactive early in the standards definition process. When it has done so, it has often been effective. DoD requirements often lead commercial standards. However, programs may have to pick standards before the eventual free market winners are known. The program may guess wrong, and have to be changed over to the winning standard. In most cases, however, DoD is far better off guessing which standards will be commercially adopted and recovering when wrong, than funding the development and support of its own unique solutions. Also, as standards eventually become obsolete, migration plans will be necessary.

Applying an OS Process to subsystem upgrades of legacy systems -- the bulk of the DoD inventory -- can be quite expensive. The problem is not so much the upgrade itself, but integrating the upgrade with the residual legacy architecture of the system and other interfacing subsystems. This can be particularly difficult when the residuals are proprietary, often the case in legacy systems.

By far the greatest risk of an OS Process is the rigidity of current U.S. government management and oversight processes. These are self-inflicted and entrenched. Experience shows that Program Offices can achieve astounding results when permitted to do so.

Managing to Let OS Happen. We are in an era of extraordinary technology advances providing astounding performance, packaging, and cost improvements. This should be a boon to DoD, facilitating skyrocketing capabilities, falling prices, and accelerating schedules. But DoD is not realizing the benefits of these revolutions. More typically, DoD systems become antiquated before they are fielded, parts are obsolete and unobtainable, support is a nightmare, costs soar, and the program becomes only marginally viable, jeopardizing missions, programs, and budgets. This is the result of dysfunctional management processes which must be revamped.

Systems need to be parsed and managed by the natural cycle rates of the underlying components. Some aspects, like basic structure (hulls, airframes), change infrequently throughout the life of the system. Other elements, like basic subsystem architectures and interfaces, computer operating systems and language, have a moderate change rate -- perhaps 15 years or so. As we know all too well, elements such as electronic components can have very high cycle rates, sometimes less than two years. But DoD processes are suited only to very slow evolution and infrequent change.

DoD needs to revamp its management process to coincide with and enable the natural, asynchronous cycle rates of the underlying subsystems and components. Configuration "snapshots" will be defined when particular products (ex. first flight article) are needed. It is not expected that subsequent articles would have identical detailed configurations. Systems will be defined by (1) functional specifications, (2) the configuration of low and medium cycle rate elements, (3) F^3I "sockets" for high cycle rate elements, and (4) migration plans to maintain continuous system viability.

Is such a structure of decoupled system elements plausible in the product domain? The OSTF considered the stress case of avionics for high performance tactical aircraft, a major DoD expense. Layered software architectures were found which enable portability across hardware hosts and ready turnover of application programs. In the hardware domain, consolidated, well interconnected electronics enclosures located centrally in the fuselage and outboard equipment bays can now provide high performance commercial backplanes to allow subsystem electronics to evolve with minimum need for Group A (airframe) modifications. The OSTF concludes that product configurations which enable natural cycling of system elements are indeed available for most DoD applications.

OS Process Status Within DoD. The OSTF has suggested a new way of thinking about configuring Forces and systems, and managing development and logistics programs. Being new, one might expect adoption within DoD to be modest at best and that is very much the case. At the Force level, OS attributes are considered only narrowly (ex. C4ISR interoperability) and are not embraced as a broad enabler, even in areas of seeming great importance such as interoperability of logistics management systems. The OS Process is not seen as a cornerstone competence, a highly leveraged solution for long-term viability and effectiveness. Although there are heartening grass roots efforts such as the Pacific Fleet command ships, within the new warfighting initiatives such as JV2010 and the service equivalents there is little substantive funding of real projects. Within the operational community we found few of the requisites for a real initiative, such as plans, metrics, training, and investment.

Within the acquisition and support community there are exciting examples of truly inspired work; but looking across DoD as a whole, progress is minimal. OS attributes are not genuinely embraced and demanded by the Services and, as with the operational community, the requisites are not in place. Legacy systems are particularly disadvantaged due to the lack of funds to upgrade system architectures. The support community is in extremus. In cases where the very survival of a system is threatened, such as the predecessors of the Army IEWCS and the Navy submarine combat control system, Program Offices have been permitted to make quantum advances and have achieved notable successes. However, these techniques are not widely institutionalized.

Revamping Program Management and Oversight Processes Capturing the OS nuggets of (1) continuous viability of Forces and systems, (2) architecture-driven modularity, and (3) managing to the natural cycle rate of the contributing elements, will require an extensive revamping of DoD program management and oversight processes. An OS Process must become a mindset and core value of DoD. We have dead-end, stove-pipe systems because we demand and reward little more. The requirements process must demand OS attributes.

The very concept of what a system is must change from a static "point-solution" view to thinking of systems as crucibles to capture and exploit the explosive beneficial change occurring all around us.

Today, to be static is become obsolete and at risk. Yet DoD management and oversight processes massively impede the dynamism DoD so desperately needs. The concept of baselining is as important as ever, but needs to be redefined. Rather than the historic detailed configuration control, products needs to be baselined to functional specifications, an architecture, F^3I interface specifications, and a migration plan for continuous viability.

Revamping of contracting, the EMD process, test and evaluation philosophy, and internal and external oversight is required. Contract structures need to be realigned to conform with the architectural partitioning. DoD and congressional milestone exit criteria need to be revised.

Funding categories ("color of money") are particularly dysfunctional. Technology turnover and obsolescence problems transcend the classic funding categories and should be managed as an integrated whole. Program Managers need not only full life cycle responsibility, but corresponding authorities and resources. Color of money issues are crippling and are being separately addressed by OSD. The OS Process adds further urgency.

A glimmer of hope is offered by industry. When business is truly threatened, industry has often done well leveraging Open Systems, to the extent permitted by DoD procedures. DoD should seek to leverage the enormous capabilities of industry.

Implementing an OS Process: Incentives and Disincentives. Implementation ought to be easy: the technology and methodology is before us. However, implementation will **not** be easy because the impediments are largely institutional, self-inflicted and entrenched. Current DoD processes impose massive impediments. The notable successes which have been cited are monuments to constructive circumvention. DoD has legions of very good and motivated people: the most effective thing that can be done is merely to get out of the way, to unshackle the work force. But DoD processes are so entrenched that unshackling will not happen without aggressive executive leadership.

Recommendations This OSTF recommends:

- A Special Assistant for OS Process Implementation be established within the immediate office of the SecDef, perhaps reporting to the DepSecDef.
- The new Special Assistant develop a roadmap to (1) establish a formal OS Process to be mandated for all new and legacy system upgrades, (2) revamp management and oversight processes, (3) establish incentives, and (4) attack impediments.
- In the meanwhile there are some immediate actions which can be taken:
    - The JCS amend all MNS and ORDS to require OS Process attributes and continuous system viability
    - The USD(A&T) and ASD(C4I):
        - Direct all system programs to develop a Viability Risk Mitigation Program
        - Grant interim relief from legacy management processes to permit Program Managers to adopt preliminary OS Processes
        - Establish Architecture Control Boards with supporting structure for each key architecture
        - Designate a few pathfinding OS Process major programs
        - Establish a process for consistent DoD participation in commercial Standards processes
        - Include an OS Process module in DoD professional education
        - Expand OS-JTF role and capabilities to become the secretariat for the new Special Assistant
        - Establish a DoD/Industry OS Process Coordination and Advisory Council
- SecDef hold kickoff offsite with Chairman, Service Secretaries, Chiefs, CAE to secure personal commitment, launch DoD initiative, request Congressional, Administration, and Industry support

Tasking

- Formal Terms of Reference*
  - What are benefits and obstacles to an Open Systems Process?
  - What would we have to do to realize the benefits?
  - New and legacy systems; not just IT
- Initial discussions with USD(A&T), OS-JTF
  - "DoD has been working on Open Systems -- this is important, but we haven't gotten our arms around it"
  - "Need the Task Force to recommend a conceptual framework for proceeding"

This is not an esoteric report about formal "Open Systems" --
It is about exploiting Lessons Learned from the Open Systems experience to achieve a major advance in DoD combat and acquisition effectiveness

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- Terms of Reference – Defense Science Board Study Task Force on Open Systems, 14 July 1997
  - Examine benefits of, and obstacles to, application of OS Approach
  - Examine application to:
    - New, developed, and fielded programs
    - Across the spectrum of systems, not just IT
- Initial discussions with the USD(A&T) and the Director of OS-JTF addressed
  - What process needed to get broad acceptance
  - Recommend revisions to DoD policy, practice, and investment strategies

Members*

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Mr. John Wehmeyer	SRI International
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See Appendix B 11

Conclusions

- Open Systems Process is fundamental to many DoDpriorities that are dependent upon a process-based approach
  - JV 2010 and Service equivalents - Reduced cycle time and ownership costs
  - Force modernization - Favorable industrial base realignment

  Open Systems Process is a Warfighting and Title 10 *essential core value*
- Forces, systems, and processes need to leverage change:
  - Configure Forces, systems and processes for continuous viability
  - Achieve architecture-driven modularity
  - Manage to the natural cycle rates of underlying components
- Open Systems Process is based upon a hierarchy of architectures and standards developed with a performance-based collaborative approach
- Unlikely that DoD can implement Open Systems Process by usual bureaucratic means
  - *Open Systems Process is a cultural and budget challenge-* process is within our grasp
  - Requires support from DoD, Administration, Hill, and Industry
  - Need to reconfigure Forces, systems, and management processes
  - Removing impediments is most important

Requires aggressive leadership, SecDef and Service Secretary championing

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Although not yet widely recognized, a number of DoD priorities can be achieved only with a massive infusion of an OS Process and related investment to implement OS architectures. Example priorities:

JV 2010 and the Service equivalents are highly dependent upon rapid, collaborative responses with distant ad hoc forces and all the associated planning, deployment, and sustainment tasks -- which are in turn dependent upon a genuine Plug & Play capability across the Forces.

- Force Modernization is severely strained in the current budget and, in the opinion of some, may worsen dramatically. The economies, expediencies, and ability for tech refresh will be essential for programs to be sold and remain viable.
- Reduced Acquisition Cycle Time and Total Ownership Cost are being driven in the wrong direction by recent developments such as a consolidating industrial base, uneconomic lot buys, dwindling supplier base, and program redirections. OS is a common denominator which can dramatically improve both Acquisition Cycle Time and Total Ownership Cost by leveraging existing architectures and commercial investment and market volume.
- Maintaining competition in the middle industrial tier is a concern for DoD with consolidation at the large system tier. Middle tier contractors are under pressure from reduced budgets and increased use of COTS at the component level. An OS Process can potentially serve both DoD and industry by nurturing middle tier competitive opportunities.

OS and the OS Process is not just an "OSD/JCS joint thing" -- it must be recognized as an ***essential core value*** for Service Warfighting and Title 10 responsibilities.

DoD Forces, systems, management processes, and oversight mechanisms are too oriented toward static solutions for a static world, defying the realities of today's world. Such an orientation is a road to failure, as seen all around us in force deployment problems and programs at great risk for being no longer viable. DoD Forces, systems, management processes and oversight mechanisms all must be re-envisioned and reconfigured to leverage change so as to remain viable throughout the entire life of the Forces and systems.

Specifically, we need to reconfigure Forces, Systems, and key processes to enable continuous evolution for life-long viability. Continuous evolution can be economically and technically achieved only through extensive use of smart, architecturally-driven modularity, whereby Force and systems are seen as a structure of F^3I "sockets" to enable the natural cycle rates of the underlying components.

Finally, DoD management and oversight processes must be revamped to enable the needed continuous evolution from requirements generation and system concept development through field logistics support. *Current processes are hostile to the needed OS measures.* The recommended OS Process is based upon a hierarchy of architectures and their associated interface standards. A well crafted hierarchy is necessary to simultaneously achieve the benefits of Plug & Fight, Plug & Play, and the economies of commercial components. These are each unique attributes with their own sets of enabling conditions. The architectures required to achieve each attribute are different and must all be carefully coordinated or they will thwart each other.

Each architecture and the associated interface standards should be developed and maintained with a performance-based collaborative approach in which Line Authority establishes the end objectives -- the "what" -- and the stakeholders determine the "how."

Although the basics of OS Process are in hand and readily understood, DoD will not achieve widespread implementation by its natural processes. OS Process is an *institutional* challenge. DoD must revamp a number of processes, something DoD does only with great pain. The transformation needs to include oversight processes as well and will require support from throughout DoD, the Administration, and the Hill. Industry will have a large role to play and that support should be requested.

This DoD OSTF and the OS-JTF have each concluded that that establishing real incentives and removing the impediments to OS implementation is a critical requirement. Each Task Force has identified a number of impediments and these should be explicitly attacked.

These are radical recommendations for DoD and successful implementation will require aggressive leadership, championed by the SecDef and Service Secretaries.

Some Terms

- A remarkably small vocabulary is used with little differentiation to describe a broad range of concepts, hindering critical thinking and effective communication
- For this report we use the following terms to differentiate key concepts:
  - ***Plug & Fight*** **(Force Level)** or ***Plug & Play*** **(Component Level):** The ability to readily incorporate functionally compatible parts on short notice
  - ***Open Systems Process (OS Process):*** The process of achieving Plug & Fight/Play
  - ***Architecture:*** The overall structure of a solution
  - ***Open*****:** Modular architectures with completely defined and publicly available interfaces, supported by consensus-based standards
  - ***Openness*****:** The degree to which an architecture or standard is open
  - ***COTS:*** A commercial catalog item -- ***COTS is not necessarily Open***
  - ***Practical Open:*** Most practical [vs. most pure] Openness
  - ***F^{3}I:*** *Specifying* Form, Fit, Function, and Interface (F^{3}I) to permit Plug & Fight/Play

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The maturity of a discipline is often reflected in the richness of its taxonomy. For example, it is said that Eskimos have more than thirty words to describe snow. By this measure, the general field of OS is still very much in an infant state. The OSTF has found that while a number of sophisticated, multidisciplinary concepts need to be carefully understood and treated with precision, the working vocabulary with which to accomplish this is on the order of only a half dozen phrases. The lack of a specific vocabulary and definitions greatly hindered effective communication with our many contributors and within the OSTF, and confounded critical thinking. Therefore, for the purposes of this Report we have adopted the following specific terms to differentiate between critical concepts:

Plug & Play is the ability to readily integrate the components of a modular system as needed at the moment. This modularity enables graceful evolution of the system to meet changing circumstances, and ready adaptation in times of stress.

Plug & Fight is the Force-level equivalent of "Plug & Play" and is the ability to constitute and integrate force elements as needed at the moment. Widely implemented in U.S. forces, this attribute would enable the type of quick reaction, ad hoc expeditionary operations envisioned by JV 2010 and the Service equivalents.

Architecture. An architecture defines the overall structure of an entity and its components, and the interrelationships of the components. OS architectures rely on physical modularity and functional partitioning of both hardware and software based upon well controlled F^{3}I interfaces to enable Plug & Play and Plug & Fight.

Open. Open indicates the pure case of architecture-driven modularity where the architecture and interfaces are well defined by public interfaces maintained by consensus-based processes.

Openness. The degree to which an architecture, interface, or module is Open in the pure sense of the word.

Practical Open. In choosing architectures and standards, there are many considerations in addition to the degree of Openness -- for example, how well adapted the standard is in the intended community, the maturity and expected continued support of the standard, etc. The OSTF refers to the optimum balance of these sometimes conflicting factors as "Practical Open."

F^{3}I. An modular system can be thought of as a structure of "sockets" which permit individual modules to be changed when needed and to evolve at their own natural pace, so long as the socket discipline is strictly maintained. Individual sockets are defined by a Form, Fit, Function, and Interface (F^{3}I) specification which is strictly enforced within the system-level architecture

Why Do We Care?

- Here is what the leadership has said:
  - **JV 2010:** "Applications of new technology will transform the traditional functions of maneuver, strike, protection, and logistics. *These transformations will be so powerful that they become, in effect, new operational concepts ....* These operational concepts will provide our forces with a new conceptual framework."
  - **Concept for Future Joint Operations:** "The key characteristic we seek for our Armed Forces is the ability to conduct dominant operations across the full range of possible missions."
  - **Secretary Cohen:** "In March, I went out to see the U.S. Army's Force XXI experiments .... It was an awe-inspiring demonstration .... Force XXI is the much-vaunted Revolution in Military Affairs made real .... I knew that the technology I was seeing was key to U.S. military superiority in the future."

But DoD is already on a downward spiral, even with today's missions ...
It is unlikely that either JV2010 or the Revolution in Military Affairs can occur without a major change in how we configure our Forces, Systems, and Processes

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It is the view of the OSTF that *Joint Vision 2010 (JV2010)* represents a sound and thoughtful roadmap to the future for DoD as it works its way through the thicket of uncertainties and alternative futures that it faces in the aftermath of the Cold War. While accommodating change is always difficult, the new and uncertain world which has resulted from the fall of the Soviet Union presents DoD with one of the most significant discontinuities it has ever faced.

The end state that JV2010 describes is composed of the aggregate capabilities that our forces must posses to ensure U.S. military superiority, leadership, and the security and prosperity of the American people in the 21st century. JV2010 describes an end-state set of capabilities which are radically different from those our forces possess today.

It is clear that DoD has expended, and is still expending, significant resources in the process of thinking about the future and attempting to understand what qualities and attributes our forces must possess to maintain military superiority in the 21st century.

It is equally clear that it is unlikely that either JV2010 or the Revolution in Military Affairs will occur without a major change in how we configure our forces, systems, and processes.

Why We Care
- Warfighting -

- Emerging CONOPS will be pick-up actions: collaborative, quick responses to uncertain enemies in remote, poorly understood locations with little infrastructure
  - Ability to quickly integrate and execute will be a corewarfighting competency
  - Quick response requires ability to constitute, configure, and execute Forces on the run
  - Highly integrated, mutually dependent, joint operations with coalition Forces
- CONOPS massively dependent upon ready constitution, dynamic collaborative planning and execution, and JV2010-style sustainment
- Can't get there from here without a quantum increase in Plug & Fight capabilities across the force: training, planning, deployment, ops, sustainment, support
- Analogous to Reliability for the Air Force in early '80s

"The high availability of our front line aircraft was a major factor in the outstanding Air Force performance in Desert Storm! Plug & Fight has a similar potential for quantum improvement and could be our next great leap forward"

General (Ret) Larry Welch, former Chief of Staff, U.S. Air Force

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Future military operations are likely to be rapidly unfolding, pick-up actions that require collaborative, quick responses to uncertain conditions in remote, poorly understood places with very little (or no) infrastructure to support military operations. Success will dependent upon our ability to quickly constitute, configure, and execute forces on the run. Our structure will require mutually dependent, joint operations between the Services and coalition forces. They will be massively dependent upon ready constitution, dynamic collaborative planning and execution, and the Focused Logistics envisioned in JV2010. The old approach, although highly successful in its time, simply will not work well enough to ensure success in the emerging warfighting environment.

Why We Care

- Title 10, Training and Equipping the Force -

- Acquisition and Support
  - Current processes are based on a world which no longer exists
    - Requirements and technology evolved slowly in most areas
    - Parts presumed to be available at reasonable costs over long periods
    - Could repair, rebuild, or replace from detailed drawings, part lists
  - Although these conditions no longer exist, our processes haven't changed accordingly
  - Our acquisition and support centers are *in extremis*
- Train-As-You-Fight
  - If training with component, joint, and coalition Forces is to be effective, Forces must be much more Plug & Fight-capable than they are today

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Equipping. DoD acquisition processes continue to echo the Cold War world in which performance mattered more than cost; requirements and technology evolved slowly in most areas; parts were presumed to be available at reasonable costs over long periods; and industry and government depots could repair, rebuild, or replace systems from detailed drawings and part lists.

Although these conditions no longer exist, our processes haven't changed accordingly. Program managers continue to be incentivized according to the old standards, with predictable poor results.

Our acquisition and support centers suffer particularly from the rigidity and inflexibility of legacy processes. Those processes are based on the assumption that repair parts and other materiel needed in the support centers remain available. Today, components come and go in the marketplace so rapidly that much of the documentation used by repairers is out of date by the time they receive it. If this trend continues, and the cycle time for new technologies continues to shorten, then it is highly likely that support centers will become gridlocked in the course of normal operations -- never mind the loss of wartime surge capacity.

Training. If we are to train today as we expect to fight in the future, then training with other U.S. and coalition forces must have a much higher Plug & Fight content than is the case today. It is necessary that our forces train on each others' equipment. Otherwise, the level of integration needed to blend disparate units together on short notice -- leaving little time to train -- will not be achieved.

Why We Care
- Conclusions -

- The world has changed ....
  - Operational demands are up, not down
  - Investment and O&S accounts likely to remain at reduced levels
  - Changes in industrial base are leaving DoDbehind
- DoD can neither *Equip, Train, Support, nor Fight* in this new world without major advances in Plug & Fight capabilities
- OS Process is no panacea, but enduring solutions are unlikely without it
- We find no viable or practical alternative

OS Process is critical to future warfighting and Title 10 responsibilities

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The world has changed.

Despite the fact that we won the Cold War, today's operations tempo and operational demands are up, not down. As a consequence, all of the Services are facing increasingly severe retention problems. Skilled people are leaving the Services at unacceptably high rates.

O&M accounts are likely to remain at reduced levels, despite a continuing high number of deployments and increased operations tempo. Without substantial changes in the way we do business, this problem can be disastrous in the near future.

Changes in the industrial base are leaving DoD behind. Many suppliers are disincentivized by DoD's antique processes and by the shrinking and unique market it represents. At one time DoD could dominate technology markets, but the explosion in non-military technology has reduced DoD from the major force in many markets to a bit player who can safely be ignored. Some companies have abandoned the DoD market, and will only sell to DoD and its contractors on a standard commercial basis.

For these and many other reasons, it is the view of the OSTF that DoD can neither *Equip, Train, Support, nor Fight* in this new world without major advances in processes which will provide a solid foundation for developing Plug & Fight capabilities.

The OS Process is not being advanced as a panacea or "silver bullet" for these problems; rather, the OSTF believes that enduring and effective solutions are unlikely to happen unless they are built on the foundation that the OS Process provides.

We have searched for, but found no viable or practical alternatives to, the OS Process as a solution to these problems.

Pilot Open Systems Efforts Have Produced Impressive Results

- Army Intelligence and Electronic Warfare Common Sensor (IEWCS)
  - Interchangeable and interoperable common modules; VME interface standards
  - Replaced six legacy systems; increased interoperability; reduced development & production costs by 40%, R&D time by 64%, EMD time by 29%
- Navy's New Attack Submarine (NSSN)
  - OS Architecture implemented through an OS IPT & Modular Design
  - 2:1 reduction in development time
  - Greater than 5:1 reduction in development costs
  - 4:1 reduction in procurement cost
- F-15, F/A-18, AV-8B common processor pilot programs
  - Cross-program modular HW & SW interfacing with legacy platform and subsystems
  - Expecting about 50% improvement in development and O&M costs
- Seventh Fleet Command Ship (USS Blue Ridge)
  - Converted Mission and Housekeeping functions using OS Process and COTS
  - Modified ship structure to enable open, rapid reconfiguration

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Several pilot OS efforts are providing very encouraging results. These initial efforts substantively support the notion that an OS Process tailored for DoD, as both a technical approach and a preferred business strategy, will enable superior combat capability fielded more quickly and affordably.

Such pilot projects include:

(1) The Army's **Intelligence and Electronic Warfare Common Sensor (IEWCS)** System, which replaced six separate and unique SIGINT/EW legacy systems, each having little commonality of hardware or software, and each with different operations, support personnel, and facilities. The systems had become inadequate and unaffordable: replacement in kind was out of the question. The systems were no longer viable and critical battlefield missions were endangered.

The Army applied the concept of architecture-driven modularity at the PEO level. Interchangeable and interoperable common hardware and software modules, mostly COTS, were hosted on four types of Army and Marine tactical platforms. Each IEWCS configuration has demonstrated vastly superior technical and operational performance capabilities. Additionally, the IEWCS development demonstrated significant schedule and costs improvements relative to traditional Army program acquisition programs: R&D time improved by 64% (including an 18-month schedule slippage needed to initiate the OS Process) and EMD time by 29%. As a result of implementing OS, the IEWCS system achieved $35M, $680M, and $900M cost avoidance in R&D, production, and O&S respectively for the Army and Marines.

Most importantly, a robust, affordable mission capability is now being fielded and is much demanded by the appropriate CinCs. Missions were saved.

(2) **Navy Submarine Combat Control and C^3I systems.** The predecessor BSY-2 Combat Control System and some C^3I systems had become unaffordable, jeopardizing a critical mission. An OS architecture and COTS OS-compliant components were used to develop a much more effective and affordable alternative for the New Attack Submarine (NSSN) and other submarine programs. The C^3I component development time is less than 50% of that required by its predecessor BSY-2. The signal processors have 25 times the capacity of the BSY-2, and the data processors 57 times the capability of the BSY-2. Yet, development costs are approximately 18% and shipset costs are approximately 22% relative to comparable BSY-2 system costs. Again, a robust mission solution is fielded in a severe budget environment.

(3) **F-15, F/A-18, and AV-8B common software and processor upgrade.** Addressing long-term weapon system viability, the prime contractor is applying an OS-based implementation across three very dissimilar aircraft from three different Services. Rehosting legacy code, common algorithms, and software modules were developed which could be executed on different hardware, and were successfully flown on all three target aircraft interfacing with disparate "generations-old" legacy subsystems. Common processors are being developed under parallel programs, again interfacing with myriad legacy subsystems while providing significantly increased throughput and memory. These improvements will accommodate software upgrades to high-order language and object-oriented design as well as provide for increased functionality in the future. The use of Open standards and commercial parts results in unit prices that are roughly half the cost of the legacy computers and eases the incorporation of new technology as it evolves.

(4) Recent upgrades to the mission and housekeeping functions for the Seventh Fleet command ship, the **USS Blue Ridge (LCC-19),** have used OS and COTS components extensively. The OS-based implementation will provide not only significant technical advantage, but will enable U.S. warfighters to innovate on the spot, permitting dynamic functional adaptations in support of fleet operations. Such Plug & Fight and Plug & Play modifications, using OS architecture and components, permits more flexible and rapid reconfiguration to meet future fleet warfighting requirements. For example, in the first ever Air Force preparation of an Air Tasking Order aboard ship, 13th Air Force prepared the daily ATO aboard Blue Ridge in support of the 10,000 man, 300 aircraft Tandem Thrust exercise with Australia. Perhaps most importantly, this modernization was largely accomplished by the staff and crew of Blue Ridge, an example of OS enabling the innovative prowess of the individual U.S. warrior.

An Open Systems Process Tailored for DoD

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The Vision

Enabling DoD to affordably configure and integrate Forces, systems, and processes for high combat effectiveness and life-long viability

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Meeting the challenges identified in the Why We Care section requires that our forces be agile, our systems adaptable, and that all investment be configured wisely for maximum economy, reuse of investment, and continuing technology refresh. The ability to readily integrate as needed, at the moment, at all levels -- from forces to systems to components -- is rapidly becoming a critical DoD need.

Smart modularity of forces, systems, and management processes is necessary to meet this need. The techniques for achieving such modularity are within the grasp of DoD and can be realized through an OS Process such as recommended by the OSTF.

This is our vision:

- That DoD energetically embrace an OS Process of some sort and launch an aggressive program throughout all DoD entities to reconfigure the very fabric of DoD; that an OS Process become an ubiquitous core value and mindset.
- That in achieving OS attributes, DoD will realize a quantum improvement in force effectiveness and use of our critical resources.
- More specifically, Plug & Fight/Play capability will:
  - Improve the ability of DoD to rapidly and effectively respond to the new threats from the outside that demand quick and effective reaction by joint U.S. and allied forces.
  - Enhance DoD capability to create flexible systems and forces by effectively exploiting the opportunities provided by the commercial market place and new technologies, and keep these systems viable through their desired life times.
  - Create an effective approach to adapt to the new business and engineering methods within DoD.
  - Increase the DoD and Services' ability to realize *JV 2010* vision.
  - Enhance interoperability and affordability via Practical Openness.

Critical Open Systems Lessons Learned for DoD

The Nuggets

(1) Configure Forces, systems and processes for *continuous viability*
(2) Achieve architecture-driven modularity
(3) Manage to the natural cycle rates of underlying components

- U.S. Forces, systems, and processes severely threatened by their lack of agility in dynamic world
- For systems, today's threat domains include not only combat capability but also inadequate affordability, response time, sustainment, eroding supplier base

Must configure for constant evolution in a dynamic world

- Our Forces and systems must be rich in "smart" modularity, driven by architecture, and configured as a hierarchy of modular "sockets" enabling adaptation in a dynamic world
- Must revamp our management processes to encourage and leverage the natural cycle rates of the underlying components

The primary benefit of the OS experience for DoD is not so much about mandating pure "Open" solutions as it is about extensive, wise modularity and a significantly enlightened management approach

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Militaries are prepared to fight either the last war or the war of their leaders' youth. Fundamental change requires either a disaster or a period of about two military careers. Today, the natural cycle rate of technology change occurs within the tour of duty of a military officer -- never mind over the entire career. Today, we seeing a Mean-Time-to-Obsolescence that is shorter than the Mean-Time-to-Failure. DoD forces, systems, and processes suffer greatly from an inability to keep up.

Examining the OS experience, the OSTF identified three critical concepts for DoD:

- The need to focus upon **continuous viability** as a critical attribute. Ironically, today's systems are primarily falling prey to unaffordability, sustainment problems, incompatibility with the force, obsolescence, and eroding supplier bases. Just as robustness against the enemy threat is a critical system criteria, so must be the continuing viability of the system in the realities of today's world.
- Extensive **architecturally-driven modularity** is requisite for needed agility, ability to reconstitute and integrate as needed, commercial economies and reuse, and technology refresh to maintain compatibility and supplier bases.
- Today the world *is* change and DoD needs **management processes which enable change** as an essential attribute rather than as an evil to be resisted. Much of DoD's acquisition, support, and oversight philosophy is now dysfunctional and needs revamping.

Note that the OSTF does not endorse a pell mell rush to pure Open solutions. There is a great need for rigorous controlled modularity, but we observe that in the rest of our lives the best available solution is often not the most pure solution. We are therefore putting the greatest emphasis on developing high integrity techniques for identifying the most optimum solution rather than mandating a particular outcome.

Analyzing and Addressing Viability Risk
- A Strawman Approach -

The fact of program-threatening evolution is *absolutely certain* --
Need to develop explicit risk mitigation strategies

Step 1: **Risk Analysis:** Characterize expected evolution and cycle-rate of the key factors affecting viability *throughout the life* of the product

- Likely topics include: affordability, technology, subsystem characteristics, external interfaces, requirements, supplier base
- (Attributes for life-long viability probably needed just to get through EMD -- witness F-22)

Step 2: **Apply Plug & Fight/Plug & Play/Openness as critical attributes**

- Example program tasks: concept development, analysis of alternative, acquisition strategy, tailored program management scheme
- Example OS topics: continuing affordability, evolving connectivity, tech refresh, suppliers

Step 3: **Demonstrate that *architecture* gets best life-long viability within available resources**

Step 4: **Include OS Process in all relevant procurement matters**

- e.g., Requirements, specifications, ***Source Selection Criteria***, etc.

Make sound life-long viability a mandatory milestone review item

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Long-term viability should be a critical system attribute and subject to mandatory acute Management and Milestone Review attention. There is a logical sequence for approaching this need:

1. Identify the key factors affecting the system's *life-long viability* and characterize their expected evolution and cycle-rate. The list of key factors will probably include the topics listed above. Estimating future evolution is difficult, but an approximately correct answer is much better than what we do today. In most cases, the *fact* of rapid change is certain but the *details* of future solutions are unknown at the time. The *life-long viability* of the system architecture and the program management structure in the face of such uncertainty is a critical system criteria. The estimate of the direction and rapidity of the evolution is used to test this *life-long viability.*

2. Analyze the degree of Plug & Fight, Plug & Play, and Openness which will provide the best *life-long viability* for the resources available. The result should be reflected throughout the system and management documentation, including such documents as listed above.

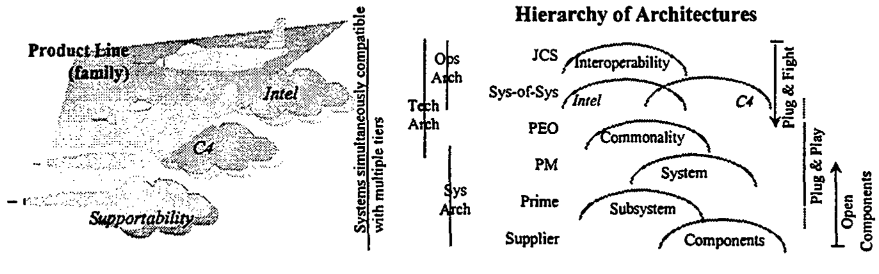
3. Demonstrate that the system architecture and standards best achieve the Openness requirements developed above (2). Legacy systems present a different challenge in that there is an existing system architecture to contend with. This existing architecture may not easily facilitate migration to a more open architecture. In some instances, such as legacy systems with very limited remaining operational utility, the best decision may be *not* to migrate the system to an Open system. An appropriate Open Systems migration plan must be established for each legacy system with viable future operational utility.

4. Include the OS Process and the Openness requirements in all applicable acquisition actions, and particularly as a source selection criteria.

The above should be a mandatory OSD, JCS, and Service Milestone Review topic.

Architecture Driven Modularity

Capturing the benefits of *Plug & Fight, Plug & Play,* and *Commercial OS* requires a hierarchy of architectures



Axioms
- Plug & Fight, Plug & Play, and Open components are related but different
- Each must be individually nurtured, but in a coordinated, mutually supportive approach
- Each must impose only the minimum essential requirements, or they will stifle the others
- Ops, Tech, and Sys Architectures each have different sponsors, as does each tier of the hierarchy
- Forces and systems must be simultaneously compatible with all relevant architectures in the hierarchy

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A hierarchy of architectures and related bodies of standards.

Many tiers of DoD have legitimate needs which will soon lead to architectures. For example, JCS is starting to explore interoperability needed for warfighting and is currently addressing some aspects of C4ISR interoperability. Presumably, in the future we will see joint technical architectures for interoperability of functions like mission planning, logistics viability and management systems, deployment, modeling & simulation, and administration.

At the System-of-Systems tier there are a number of areas like Theater Air & Missile Defense with the Single Integrated Air Picture which will result in mission-wide architectures. The Army IEWCS is a good example of a PEO constructively imposing a cross-system architecture. We can expect more cross-system architectures to be imposed by intermediate tiers (e.g. the Joint Logistics Commanders, or a Service Assistant Chief-of-Staff for Logistics). There are "building code" architectures needed for acquisition efficiencies as well as operational needs.

The OSTF foresees a world in the near future of inter-related architectures in a hierarchical construct. The architectures and their associated bodies of standards will be dynamic and provide another source of rapid change with which individual weapons systems and the supporting processes must cope.

Indeed, the hierarchy includes the weapons system tier which hopefully will be configured as a structure of F^3I "sockets" to allow lower level tiers (primes, subsystems, and component suppliers) maximum flexibility to deal adequately and affordably with demands on the weapons system and the dynamics of the commercially oriented industrial base. The industrial base will operate with their hierarchy of architectures and associated standards.

It is hard to imagine that DoD will be able to function constructively in the new, highly dynamic world without such a hierarchy of disciplined architectures.

Hierarchical constructs

The figures above suggest several useful ways of considering the hierarchy for various purposes.

The "stack of umbrellas" illustrates that many functional tiers within DoD have legitimate architectural requirements. These may result in a unique "horizontal" architectures (an "umbrella"), or they may be included in part in various "vertical" architectures.

OSD and JCS have define three architectural domains: Operational, System, and Technical. These are referred to here as "vertical" architectures and, for reference, mapped on the figure as vertical lines showing the organizational tiers most affected. Each of these architectures have their own sponsors, Operational Architectures being primarily the purview of the JCS and service operational communities, System Architectures being primarily the purview of the OSD/Service acquisition community, and Technical Architectures being a combined operational and acquisition concern.

The critical DoD interest in OS is to simultaneously capture the benefits of Plug & Fight, Plug & Play, and economic commercial components.

Plug & Fight means ready integratability and interoperability throughout the Forces. This can be achieved only with a top-down, force-wide architecture and the compliance of every related element in the force. The architecture must reference a body of standards which are truly interoperable. *In this regard, the Joint Technical Architecture is currently flawed.* In an effort to accommodate the constrains of legacy systems and Title 10 prerogatives, the JTA is a collection of standards which are perhaps individually meritorious but which are not necessarily mutually interoperable. Thus, systems can be totally compliant with the JTA and not be interoperable.

The JTA is not currently an architecture assuring joint interoperability. OSD and JCS need to mandate and enforce a single interoperable body of standards.

Complex functions may not be amenable to precision interoperability solely by standards. The inevitable differences in interpreting and implementing key standards may thwart the needed interoperability. In these cases it may be necessary to require universal use of a common kernel or processor.

Plug & Play resides in the middle tiers and is the system attribute which strives to simultaneously enable dynamic flow-down for integratability and bubble-up of commercial economies. Plug & Play is enabled when a system is configured as a structure of F^3I "sockets" permitting underlying components to cycle asynchronously at their natural rates. Basic architectural elements and F^3I sockets also have finite lives and obsolescence and the system must be configured to enable graceful evolution.

It is vital to study carefully how each attribute is achieved in the hierarchies, for attention is needed to assure that the benefits of Plug & Fight, Plug & Play, and economies of Open components are simultaneously realized. Without disciplined attention to the full perspective, it is almost certain that local optimizations will compromise the overall structure.

At the lowest tier, DoD desperately needs to capture the enormous benefits of commercial components with their large industrial investments and economies of scale. The greater this class of benefit, generally the less influence DoD has over the product and related standards. And these standards themselves have finite lives and looming obsolescence.

There exist certain axioms which apply across the widely disparate tiers of the hierarchy.

Every entity must be configured in the context of an overall architecture and that architecture should be constrained by all the architectures which affect it, including both higher tier and lower tier architectures.

It is not enough that each component is individually Open: the whole must be as Open as practical and all components must integrate well together and evolve gracefully, maintaining Openness over the life of the entity.

To this end, each tier must rigorously impose only the absolute minimum constraints necessary to achieve its legitimate requirements. To the full extent practical, only functional constraints should be imposed, leaving the detailed *how* to the lowest levels.

Partitioning for Modularity

Good modularity demands robust isolation of constituent elements, connected only through interoperable interface specifications

- Design attributes:
  - Modularity - Element substitution and renewal
  - Portability - Reuse and resource sharing
  - Scalability - Ready modernization and growth
- How much?
  - System-of-systems needs
  - Operability and interoperability
  - Commonality (horizontal, vertical, across functions)

Attributes often compete -- for example:
- MS Windows gives broad commonality but poor interoperability and reliability
- Apple gives interoperability and reliability but limited commonality

- Decomposing the system
  - Emphasize open partitioning, leverage standards, get expert advice
  - Need hard isolation of modules, interact *only* through interface specs
- Implementation
  - Designated system-of-systems and system architects
  - Mechanisms to assure local decisions don't compromise system design
  - Test attributes sought
  - Tight discipline throughout life cycle; don't let attributes dissipate

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An OS requires, as a minimum, an architecture with modularity, portability, and scaleable attributes. Interoperability is frequently defined as a Plug & Play capability that is realized when system components are shared among unanticipated users and in a variety of environments. Maintainability implies a capability to repair and extend functionality so the system capabilities can grow beyond initial implementation. However, these Plug & Play attributes often compete so that it is difficult to develop a design that maximizes desired system attributes. For example, Microsoft's Windows 95 is widely used but has well known reliability problems and does not interoperate well with non-Windows products. In contrast, Apple's Macintosh computers are known for their interoperability but are less widely used.

Although there is much emphasis in the use of standards and application interfaces, architectural decomposition also plays a significant role in achieving OS requirements. For example, command and control system functions overlap with intelligence systems and systems within the command and control system domain overlap with each other. Therefore, different system decompositions may promote Openness with one system over another.

System-of-system and system architects are needed at each level to ensure the best overall design and to guard against PM's locally optimizing their system design at the expense of other levels in the architectural hierarchy. Furthermore, system testing should include system attribute evaluations and tighter discipline is needed throughout the life cycle so that OS attributes don't dissipate.

Such an approach fosters families of modular systems and products which can then be tailored to meet specific warfighter needs.

DoD Already Understands the Basics

- Similar to Architecting for Software Development -

- OS Process in DoD today is analogous to software development 20 years ago
  - Was art, now art + discipline with axioms, institutions (e.g. SEI), and milestone exit criteria

Very good architecting is as essential for good modularity as for SW development --
A flawed architecture compromises all that follows

- Key outputs are overall structure, partitioning, and interface standards
- The basics are at hand and already understood -- ***it's mostly a matter of doing it***
- Systems architecting is a discipline of balancing dissimilar requirements such as CONOPS, schedule, performance, risk, supportability, reliability, and cost, according to the customer's relative priorities
- Only one or two attributes usually can be constrained, but good architecture optimizes the mix
- The architecture needs to follow Open principles, even if the parts are less than Open
- But even if parts not Open, must follow the OS Process tenants, or product will almost certainly be monstrous to employ and sustain

Axiom
Architecture-driven modularity is requisite to achieving OS attributes --
therefore, OS Process should be a *mandatory*and *non-negotiable* discipline
for *all activities* configuring Forces, systems, and processes

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Although not an established discipline, the notions of an OS Process are understood. Much like software engineering two decades ago, the principles are under development and examples exist. The underlying principles need to be articulated and supported by appropriate training.

Success depends on establishing the architectural underpinnings. The attributes of Plug & Play must be planned during the architecting process. A key component of this process is partitioning into components and the definition of the interfaces to those components. While there are principles to be applied during the process, it is a matter of balancing a variety of requirements and desired attributes of the system. Considerable judgment is needed, based on an understanding not only of the domain but of the available standards and products and their interaction.

Industry can provide considerable experience in implementing an effective OS Process.

Although this may be viewed as a one-pass, top-down process, in practice it is iterative. Decisions made at one level constrain the choices at the next level. When faced with those constraints at the next level, the architect may discover that the available choices preclude an important priority and will revisit an earlier decision.

Developing and Sustaining a Hierarchy of Architectures
- Some Institutional Imperatives -

- We have all been scared by blanket imposition of well-intended *causes de jour*
- While desired outcomes and constraints can be mandated, detailed solutions should be collaborative amongst the stakeholders (and be prepared to motivate intransigent stakeholder.)
- Achieving a widespread DoD OS Process will require aggressive championing, but anointed "do it my way" czars will be successfully resisted at all levels
- Through Acquisition Reform, DoD digging out from under the regulatory heap that was burying it
- ***Need for OS Process become a mindset and core value, not another massive bureaucracy***

Axioms

- **Only the vital, bare minimum constraints needed to do the job should be imposed, and at the highest functional and organizational tiers practical**
- **Our performance-based acquisition should also be our OS Process:**
  - **Higher tiers identify needed *outcomes* and assure high integrity processes**
  - **Stakeholders in the solution devise the *how***

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DoD has over the years implemented many initiatives that had a well reasoned basis, both from a technology and a business perspective. Unfortunately, too often these initiatives have been implemented by the bureaucracy through the imposition of rules that were blindly administered. As a result, the program management community has built an effective resistance to such initiatives.

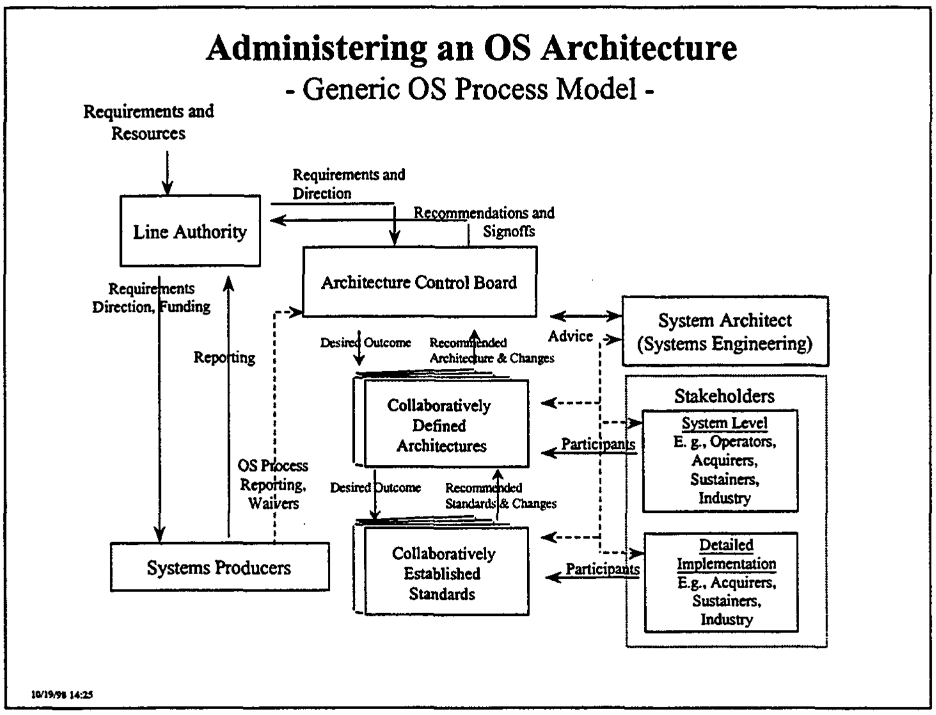
While it is often effective to have an advocate for a specific initiative, the appointment of a czar for OS will undoubtedly energize that resistance.

To be effective, the OS Process and the supporting concepts must become part of the DoD institutional processes. It must be part of the line management.

The architectural constraints placed on systems must be developed at each level and supported by line management at those levels. The application of these architectural constraints must be understood by everyone to be in the best interest of the organization from a system-of-systems perspective.

In applying these constraints, it is important that only those constraints that are essential for accomplishing the mission and goals of a particular tier be imposed. There must be strong resistance to the imposition of unnecessary constraints.

Fortunately, the performance-based acquisition approach provides the mechanism for implementing the OS Process. Higher levels define the needed outcomes and ensure quality processes and the stakeholder levels define the how.



For the practical administration of an OS architecture the OSTF suggests an adaptation of the widely understood Configuration Control Board (CCB) used by Program Management offices for decades. Adaptation to an Architectural Control Board (ACB) is illustrated in the generic model which illustrates the first order principles which would apply to all tiers of the architectural hierarchy. The slides following this suggest application of the generic model to several tiers in the architectural hierarchy.

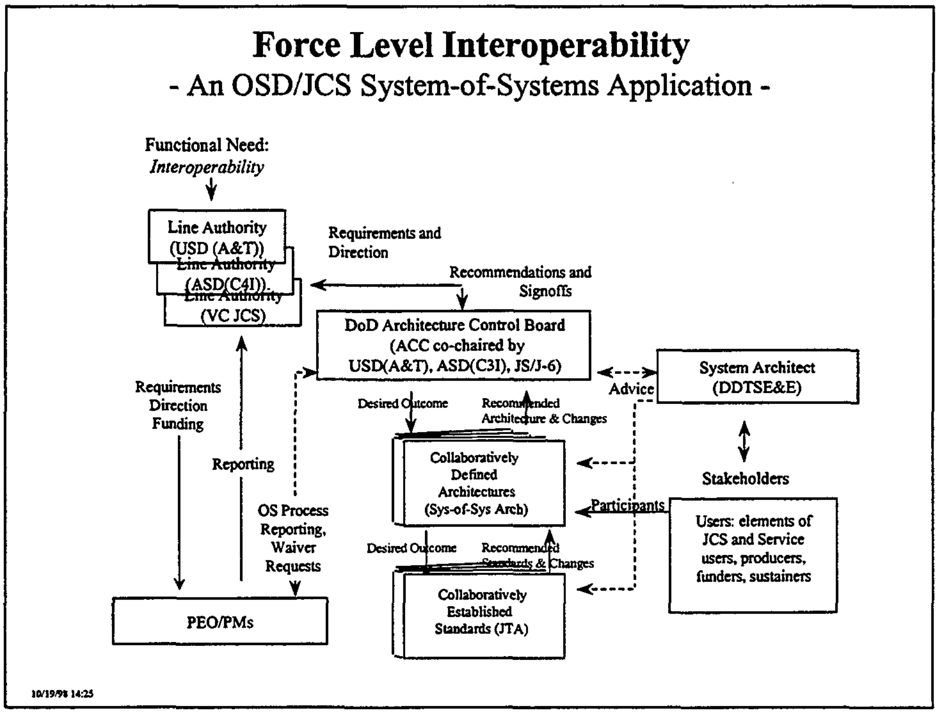
The OS process works within the existing roles and missions within DoD. The ACB advises existing Line Authority just as CCB supports a Program Director. The Line Authority responsible for each architecture oversees the process, receives and allocates requirements, responsibilities, authorities, and resources to system producers. The ACB is a review board which considers and advises on proposed actions related to architecture and compliance. A Systems Engineering function collaborates with various stakeholders in the solution to develop and maintain the needed architecture and body of interface standards, and brings their products to the ACB for scrutiny and endorsement on the way to the Line Authority for approval and imposition on lower tiers. Systems and processes subject to the architecture demonstrate compliance to the ACB and obtain endorsement as a mandatory exit criteria to milestone reviews. All waiver requests pass through the ACB for a recommendation on their way to the Line Authority for approval.

The ACB would typically be chaired by the Line Authority(s) responsible for the subject architecture. Board members would be the relevant functional directors supporting the Line Authority.

Technical support is provided by a System Architect serving in the interest of the Line Authority. System architecting is a function of Systems Engineering, organizing and shepherding the collaborative efforts of the various stakeholders to develop a responsive architecture. While the various stakeholders have access to the ACB and the Line Authority though whatever channels connect them with the developing architecture, the System Architect has a substantial power base as the primary technical advisor to the ACB chairperson, the Line Authority. It is essential that the System Architect possess substantial experience and educational credentials and understand the needs of the Line Authority and the various stakeholders. With system architecting being a function of quality system engineering, the System Architect must be supported by a competent System Engineering organization which also acts in the best interest of the Line Authority and is competent and well informed.

There is a strong preference that the architecture and corpus of interface standards be developed and maintained in a collaborative process with the various stakeholders in the structure of the solutions. Often the expertise needed to develop the overall architecture is different than that needed to establish detailed interface specification, and separate bodies may be expected.

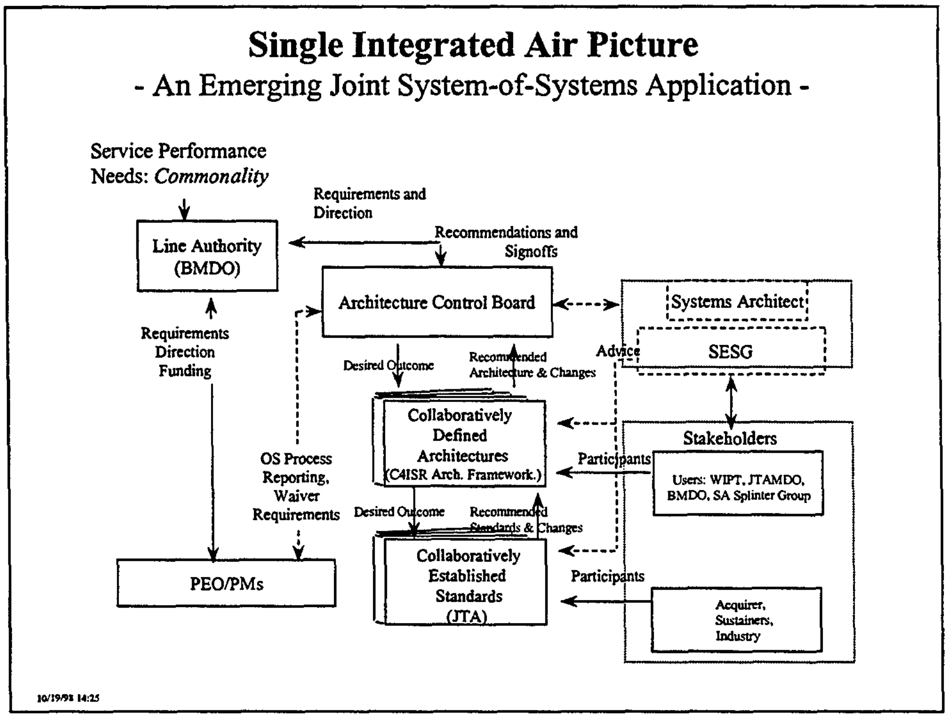
Compliance should be an exit criteria for all milestone reviews of the subject systems and processes. That is to say, ACB endorsement would be requisite for the milestone review to convene. It will sometimes be the case that exceptions to aspects of the interface standards will be in the best interest of the government. A waiver process is required, which would include ACB review and endorsement. Waivers are to be expected and should not be treated with prejudice, but the purpose of architectures is to achieve higher level objectives not addressed at lower levels: requesting a wavier should require a strong burden of proof demonstrating that the waiver is clearly in the best interest of the government as seen from all of the relevant perspectives.



Interoperability is a high order need, demanding DoD-wide architectures for each of several domains (e.g. C4ISR, mission planning, logistics management), which only can be enforced at the OSD/JCS level. Using the C4ISR domain as an example, the Line Authorities would be the USD(A&T), ASD(C3I), and VC JSC. A subject architecture would be the Joint Technical Architecture (which is not really a systems architecture at all, but rather a corpus of interface standards). The existing Architecture Control Council (ACC), co-chaired by USD(A&T), ASD(C3I), and JS/J-6, could serve as the JTA ACB. Producers are primarily PEOs and PMs.

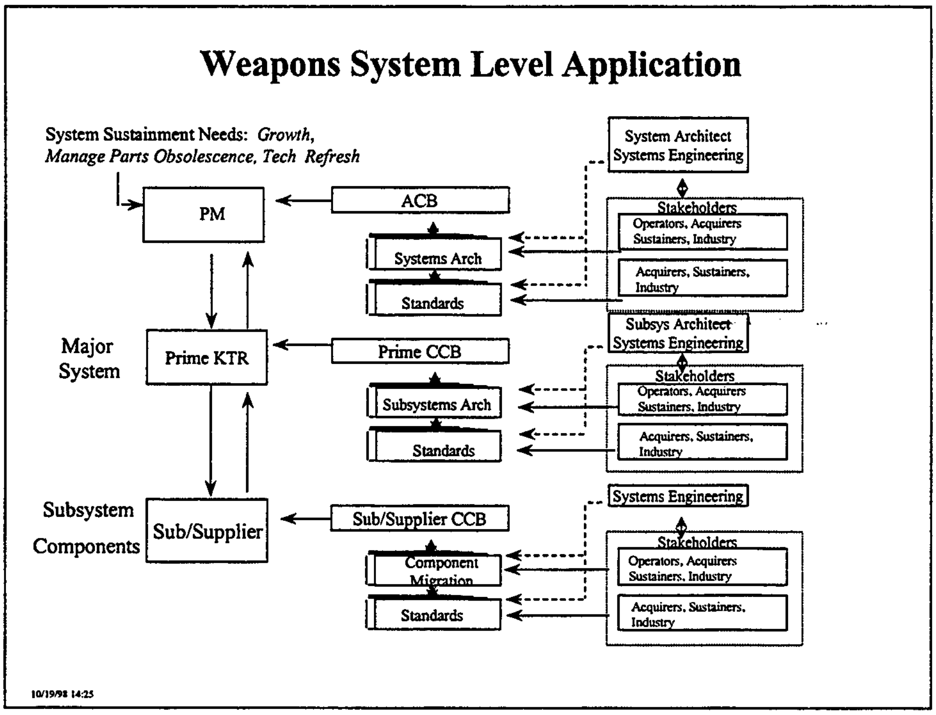
The System Architect might be the DDTSE&E, with system engineering technical support. Stakeholders include elements of the JCS and Service users, producers, funders, and sustainers. Collaborative organizations include the Technical Architecture Steering Group (TASG) and the Joint Technical Architecture Working Group (JTAWG).

In operation, maintenance, and revision proposals, requests for waivers bubble up from stakeholder groups and producers and are evaluated by the system architect, supported by the system engineering organization. Recommendations are made to the formal ACB, which considers the proposal from the perspective of the various member disciplines and which in turn advises the Line Authorities. The Line Authorities hold the final approval authority.



An example of an emerging domain architecture is the Single Integrated Air Picture (SIAP), a component of Theater Air & Missile Defense. The SIAP will depend upon systems and networking largely owned, justified, and funded by the services for other purposes. Many of the organizational functions necessary to implement a SIAP are not yet established. It appears that the Line Authority for implementation of the SIAP will be the Director of the Ballistic Missile Defense Organization at the systems command level. An ACB function has not yet been assigned to a particular entity. The systems engineering function will be assigned to a systems engineering advisory group. Stakeholder interests are being addressed by the JTAMD Working Integrated Product Teams (WIPTs). The documents produced by the WIPTs are to be consistent with the JTA and C4ISP Architecture Framework. It is anticipated that the system architect will probably be located within the BMDO organization

In the end, a sound engineering solution requires that the systems architect be a single, actual person. In addition to providing the architect function, the architect will certify to the ACB that the proposed systems architecture design will meet the requirements, including Plug & Fight/Play, given the known constraints. The architect must possess both the experience and educational credentials to be able to asses the proposed architecture and understand how it fits into the larger picture, and does not merely meet a narrow range of requirements.



At the major weapons system level, the Line Authority is the Program Manager, responsible for the system level architecture. At the system level, architectural objectives are the required functioning of the system, enabling Plug & Play to maintain system viability and flexibility, compatibility with high-tier architectures to enable Plug & Fight, and minimizing any constraints on lower tiers which might restrict the economies of COTS and transparent technology refresh by subcontractors and suppliers.

The Program Office ACB is probably chaired by the Program Manager and is an additional role for members of the CCB. The system architect may be the system engineer and is supported by the system engineering organization.

The prime contractor and key subcontractors maintain analogous structures with similar objectives of meeting program requirements while leaving suppliers maximum opportunity to keep the system refreshed at the assembly and component level.

If each lower level is producing a system, as opposed to a component, then a systems architect would be necessary for certification of that design to the next higher level. At some lower level, however, the next level up might elect to rely instead on the producer's published specifications or the self-certification of the producer.

Each weapon system tier is decoupled through the use of functional specifications, F^3I interfaces, and migration plans, permitting each element to cycle at its own natural rate.

Standards and "Openness"

- Standards define the inter-module connections ("sockets") which enable modularity
- "Open" refers to use of interfaces and protocols that conform to well defined, widely used, preferably non-proprietary standards. Open standards are those developed by recognized standards bodies or the commercial marketplace. Standards may be:
  - open (or public): e.g. tires, electric outlets, some GPS data formats
  - owned: e.g. most car parts, MS Windows 95
  - de facto: e.g. 8.5" x 11" paper, typewriter keyboard
  - proprietary: e.g. most weapons systems key components
- The level of Openness refers to the system design level at or above which interfaces conform to Open standards
- The level of Openness determines the extent to which a weapon system can:
  - Use multiple suppliers for competitive procurements through its total life cycle
  - Insert new hardware and software technology whenever available
  - Assign the control of design, repair, and replacement to the supplier
- An "80%" quick, Open solution which is affordable and sustainable is usually better than a functionally ideal solution which we probably can neither afford nor sustain

Axiom

Strong presumption for the "most Open" solution

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DoD has historically approached standards the way it approaches MILSPECs -- establish them and expect the world to comply. But that often misses the enormous economies of private investment in the commercial market. As a customer, DoD must shop carefully for the best products to achieve its goals for interoperable and affordable systems. As we have already discovered in the area of information technology, DoD needs to follow and influence where it can through standards groups. Ideally, well defined, widely used, non-proprietary standards are preferred; however, widely used standards usually dominate as the best choice to build OS. Widely used standards may be open (public), owned, *de facto*, or proprietary. Systems that adhere to the standards achieve a level of Openness that correlates to increased interoperability and affordability. The level of Openness determines the extent to which a weapon system can use multiple suppliers, insert new hardware and software, and assign control of design, repair and replacement.

Sometimes "Less Open" is the Best Answer
- But the Burden of Proof Should be Rigorous -

- OS Process presumes "most Open," but that is not always feasible; less Open is sometimes desirable in upgrades of legacy systems with limited remaining lifetimes where adoption of Open standards is not economically feasible
- Less Open often applies when:
  - Easiest subsystem or component changes, upgrades, or replacement are not needed
  - Cost effective insertion of rapidly advancing technology is not required during remaining life cycle
  - Cost reduction through competition is neither viable nor economically desirable
- Sometimes less Open solutions really do enable better CONOPS, supportability, functionality, and even total life cycle costs

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A pure "Open" world would be best for DoD. DoD should presume that any and all recommended solutions will be truly Open, and there should be a rigorous burden of proof for those who would configure otherwise.

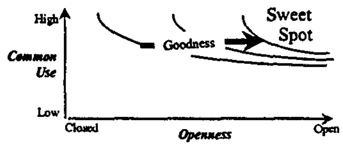
Having said that, we live in a more complex world full of examples of less-Open solutions which are truly the best answer for the particular situation. The issue, from the OSTF perspective, is less about insisting that all solutions be Open in the pure sense, than assuring that configuration decisions are well considered. And here is the rub.

The power of ready integration accrues only when the requisite attributes are wide spread. There are numerous motivations at a local level to pursue less Open solutions. It will take strenuous discipline and a more global perspective to achieve true modularity across DoD.

Legacy systems present a unique problem because legacy system upgrades for the sake of Openness alone are not usually feasible. Usually, significant system development in a legacy system presents an opportunity to incorporate standards and design changes to improve system Openness. However, many of the DoD's legacy systems have stabilized to the point that the insertion of rapidly advancing technology is not required during the remaining life cycle. Integration of OS standards and designs may not be economically feasible with such systems. Exceptions can also apply when developing a new system. New system development may be less Open because cost-reduction through competition is neither viable nor economically desirable.

OS can have some drawbacks if not applied judiciously. Blindly forcing Open standards and designs may seriously impact performance, operational capability, or create excessive costs. There are no silver bullets that can be applied uniformly across all systems. Only through sound system engineering principles can DoD obtain affordable and sustainable 80% solutions rather than ideal solutions which are neither affordable nor sustainable.

Choosing Standards



- **Criteria** (some may be in conflict -- requires engineering and business judgment):
  - Consistency with the architecture
  - Does it work well in this application?
  - Degree of Openness, breadth of use, and continued support
  - Robust capability for future evolution of system throughout life cycle
  - Extent of Plug & Fight (ex: coalition warfare ⟶ commercial standards)
- **Increased care must be used when:**
  - A standard has not matured (e.g., CORBA)
  - Proprietary extensions necessary for performance requirements
  - Multiple standards exist for the same function
  - A standard does not exist and new work needs to be reusable
  - ***Avoid hollow standards!***

"Practical Open" **= Widely used and supported, as Open as practical (wide use outweighs Openness)**

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Interface standards are of course selected in the context of the system architecture which they will serve. External conditions are also important. For example, in the graphic above, Openness is plotted against Widespread Use. "Iso-goodness" curves suggest that widespread market acceptance and support have more utility for DoD than pure Openness. Thus, MS Office is widely used although it is a proprietary product.

Industry can contribute to the standards selection process if clear success criteria are articulated by the government.

Examples of external conditions to be considered are:

A standard has not matured. A specification exists, but either products have not been created or, if the product has been created, it has not been tested in an adequate number of contexts. An example of this situation is the Common Object Request Broker Architecture (CORBA). The specification preceded an implementation. As products became available and the specification was tested, it quickly became obvious that CORBA was well suited for some applications, but not appropriate for all applications. Within DoD there was considerable pressure to select CORBA as the middleware for software systems. Since CORBA is not appropriate for all applications, settling on CORBA as the standard for all applications would have been premature.

Proprietary extensions are needed. The specifications may be complete, but do not support system performance requirements. SQL is an example of this condition. There are few developers that adhere to a strict implementation of SQL because they cannot get the database performance necessary to meet the system performance requirements. Developers frequently depend on proprietary extensions that cause a tighter coupling to the database vendor (i.e. more sole source) than a more OS approach would dictate.

Multiple standards exist. Multiple standards can meet requirements, but an engineering analysis must be done to select the most appropriate product. However, the decision can result in losses such as flexibility and scalability, or can result in increased costs down the road. CORBA and DCE support distributed computing are both acceptable choices within the JTA; however, both support different software architectures. Selecting the standard before the software architecture is developed forces the architecture to be consistent with the product, instead of selecting the architecture because it is the best fit for the problem. This is also an example demonstrating that standards are not a substitute for software engineering.

A standard does not exist. System design may call for a specific architecture or software component that does not have an existing standard. This can occur because the product is militarily unique, or no standard exists in the marketplace. For example, messaging and queuing products do not adhere to a standard.

No decision is black and white. Decision makers must consider the desired attributes for the system. Decisions must be made considering the context of the desired system properties.

Risks

- Risks associated with "more Open" options include:
  - Budget and Service investment philosophy:
    - Upfront $$ required for OS Process systems engineering
  - Backward compatibility within legacy systems can be expensive
  - Need to sway industry standards bodies; requires early proactive involvement
  - Industry concerns over proprietary data and investment for competitiveness
  - Availability of standards, their evolution & obsolescence
  - Market acceptance of emerging standards not assured; need backup plans
    - ***But, taking a chance and guessing wrong is still "cheaper, faster, better" than developing a DoD-unique solution***
- Enabling future reuse requires additional $$, offset by reducing recurring test $$ -- ex: recurring SW regression testing costs DoD $B/year
  - Numerous methodologies and technical challenges, but within our grasp
- Even with all this, ***U.S. government process impediments are the single greatest risk***

Risks are real, but are dwarfed by the benefits;
Up-front funding a major problem

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Achieving the benefits of OS requires changing a huge, entrenched bureaucracy, richly endowed with inertia, risk aversion, and accepted wisdom. Thus, process impediments provide the most imposing obstacle to realizing the benefits of OS.

Accordingly, the OSTF recommends that the OS Process for system analysis be **mandatory**. At the same time, the OSTF recognizes that making something mandatory introduces other, different risks -- i.e.:

- The risk of creating more bureaucracy, and, with it, more inertia, more risk aversion, and a new category of accepted wisdom. This risk is minimized by incorporating OS constraints into the current processes, executed by people in existing structures, rather than by creating new organizations.
- The risk that the mandatory additions and amendments to current processes will be worked around or otherwise ignored. This risk is minimized by conspicuously attaching the OS movement to the SecDef's aim to create a revolution in defense, paid for by a revolution in business practice.
- Nevertheless, the OSTF believes that bets have to be made because occasionally guessing wrong is far better than never guessing. An immediate corollary is that mechanisms have to be found to protect the careers of those who make the guesses.
- Another major obstacle is fear of failure, which often translates into a fear that bets made on standards will be losing bets for reasons beyond the control of the DoD and beyond the predictive capabilities of even the wisest technologists. Shrewd suppliers may use standards as much to fight competitors as to improve the lot of buyers' buyers. Accordingly, the standards that emerge and survive in the marketplace may not necessarily be the best choices technically.

Major changes are always fodder for those who focus on pointing out problems rather than solving problems, and movement toward Openness will provide an abundance of such fodder. Nevertheless, the OSTF believes that with support at the SecDef level, all the challenges can be overcome, and benefits realized.

One such challenge emerges because the DoD no longer has the market share to call the shots. Accordingly, it is essential that DoD provide early, proactive leadership in standards bodies. Equally, in the event the standards do not evolve in the right direction, or do not exist, then there must be a backup plan.

Of course, technical people enjoy technical elegance, so it is important to avoid natural tendencies to embellish requirements, thus locking out the industry standard. Here, enlightened leadership is needed; it must be understood that *adapting* a standard is generally equivalent to *rejecting* a standard.

Next, leadership has to realize that not all variables can be optimized simultaneously, so managers must be trained to look not only at the goals at their own level, but at the goals of levels above. For example, although the multiple-vendor, nonproprietary choice is preferred, it may be the choice that leads to enormous cost, thus contravening a key high-level goal motivating OS in the first place.

A more subtle problem is that the wide use and "lack of genetic diversity" make OS inherently more vulnerable to information warfare attacks. While worrisome, the vulnerability introduced by OS is not necessarily substantial, and should not inhibit the use of OS.

Another subtle problem has to do with proprietary interests. The interests of suppliers are not necessarily well aligned with the interests of the DoD in the Openness dimension. Historically, suppliers have made more money with non-Open systems. Additionally, there are legitimate intellectual property concerns. Such problems are difficult, but not insuperable, given the will to combine firm OS requirements with procurement innovation, all backed by SecDef level support.

Finally, time and resources have to be spent to save money. Rearchitecting, problem solving, and organizational change consume resources. Industry examples demonstrate that strong will needs to accompany strong desire if major change is to take place.

Managing to Natural Cycle Rates
- Parsing Systems by Natural Cycle Rates -

- **Mildly constrained**
  ex. Command Post, including airborne & mobile; shipboard and sub electronics
  - Rack typically isolates boards from platform environment
  - Adequate weight, space, power, cooling; rack interconnects flexible
  - High leverage of commercial technical and business practice
- **Severely constrained**
  ex. tactical missiles
  - Some commercial components but not boards
- **Tightly constrained**
  ex. Tactical aircraft avionics
  - Enclosure can isolate boards from platform environment
  - Tightly constrained weight, space, power, cooling
  - Enclosure interconnects inflexible
  - Can achieve many commercial advantages, but need new approaches

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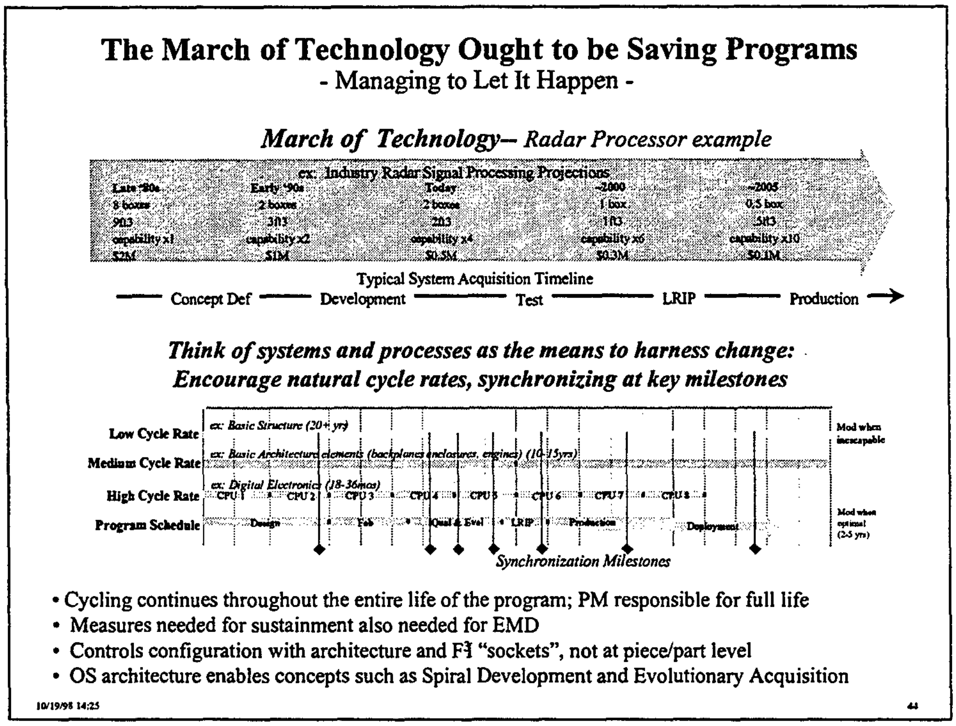
Our acquisition processes and system designs need to enable and synchronize with the natural cycle rates of the system components. We have not typically designed low cycle-rate platforms (airframe, hull, vehicle) to marry up with evolving high cycle-rate components (electronics) downstream. The high cycle-rate products which we can specify in detail at concept definition time are not what we will take to production nor support in the field, nor are the attributes we test in EMD what we take to production (ex., we should quality test software early and processor host hardware late). Therefore, frequent technology renewal, even during design and production, is a "must do" to maintain sources and support.

The high cycle-rate items are mostly electronics, and most DoD electronics can be readily configured for good commercial OS Processes. Isolating the commercial elements from the platform environment is preferable to MILSPEC hardening (ex., we already have commercial boards on tactical vehicles, surveillance aircraft, submarines). Therefore, one way to manage to natural cycle rates is to parse our systems by platform environment. This slide portrays a notional concept of platform environments and describes how each environment influences, or constrains, our use of commercial products to meet mission requirements.



Technology is advancing at an extraordinary rate, particularly in electronics and information technology. The top graphic estimates the advance of Airborne Radar Signal Processing over about 25 years, compared to the deployment cycle of air superiority aircraft (ex. F-22). We would expect such multiple quantum technology improvements to be miraculous windfalls for the development program, perhaps even saving the program in a down budget.

But such is usually not the case. Why? Because our program management and oversight processes are amazingly poor at capturing advantageous advances. In fact, the processes are so rigid that improvements actually destabilize programs and become a threat. In the current era, change is so frequent and profound that we cannot keep our systems viable and, as a consequence, programs are at best troubled at every stage of their life cycle; at worst, some are dying. IEWCS saved a whole suite of programs that would otherwise have lapsed as unaffordable; F-22 can not keep its configuration stable long enough to get through EMD. Ironically, many of the measures necessary for full life cycle viability and often unfunded by the Services are now necessary just to get through EMD.

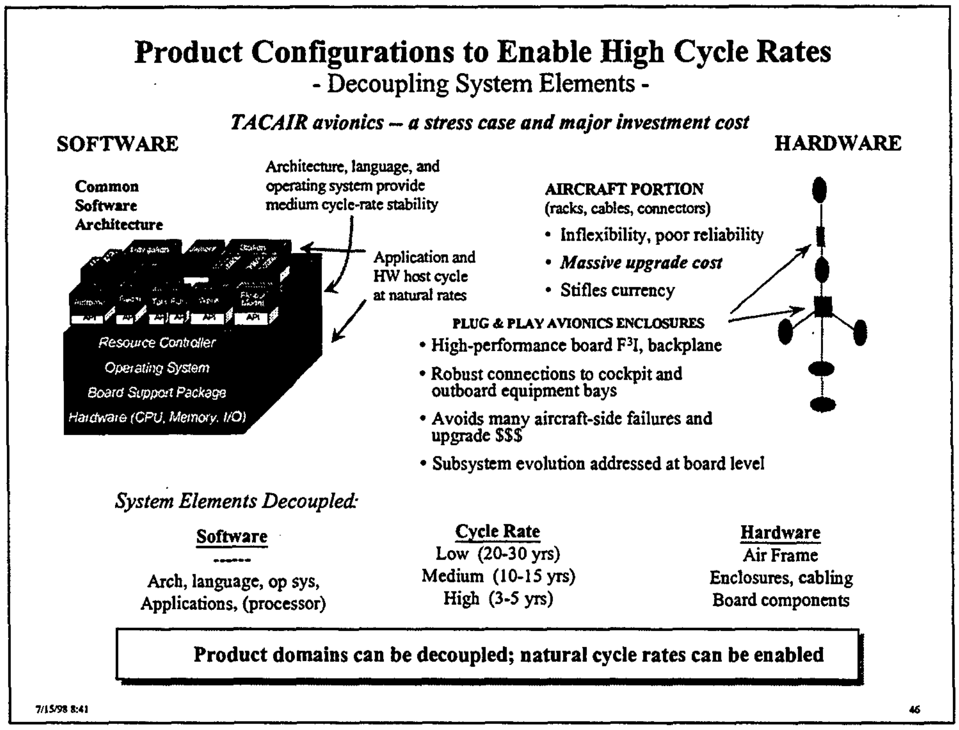
Re-envisioning our systems and our program management processes is a survival issue

We are absolutely assured of the rapid evolution of requirements, external interfaces, and the component building blocks of our systems. Instead of designing programs to withstand the ravages of change, we must configure our systems and management processes to be crucibles to leverage change for continued relevance and viability. We must revamp management processes to permit the underlying components to cycle at their natural cycle rates, while having the whole synchronize at key configuration milestones, such as fabrication of qualification articles or release of Long Lead for Low Rate Initial production (LRIP).

Upon examination, we note system components can be parsed into groups with significantly different cycle rates. Basic platform structures, for example, are often stable for 20-30 years, and we now have 40-50 year examples (B-52s). By contrast, basic architectural elements such as operating systems and backplanes, electronic enclosures, and engine interfaces may be stable for 10-15 years or so. Electronic components may lapse after 18-36 months. A program manager today knows that he will probably have to evolve his operating system and backplane structure before the first production run, and that qualification test, Initial Operational Test and Evaluation (IOT&E), and LRIP product will all have different board-level electronic components. So he also knows that it will be nearly impossible to maintain all the same-type aircraft on base at an identical configuration, and it is unlikely that even any two aircraft are identical at any point in time.

Clearly, DoD must tailor the system configuration and program management processes to the natural cycle rates of the products. We must view systems as a construct of F^3I "sockets" which permit asynchronous evolution of the components which plug into each socket. We must assure the operational adequacy of the functionality of the overall architecture. To capture the enormous advantages of a very dynamic industrial base, we must adopt a hierarchy of subordinate architectures to permit lower tier participants to evolve at the subsystem, board, and piece part levels.

Such robust architectures will enable a whole range of DoD objectives such as reduced cycle time and reduced life-cycle costs, and management strategies such as Spiral Development and Evolutionary Acquisition.



Is it plausible to configure actual products to permit asynchronous cycling of underlying components? The OSTF examined TACAIR avionics as a highly leveraged stress case -- aviation overall is a major (<50%) portion of the DoD investment accounts, a significant portion of complex aircraft costs is avionics, and many avionics assemblies are difficult.

There are both hardware and software constructs which decouple components, potentially enabling asynchronous cycling of high rate items and even medium rate architectural elements.

A layered software approach -- such as represented by the graphic to the left -- has been used by recent programs such as the LM Submarine BSY-2 Combat System replacement and the Boeing Oscar TACAIR data processor. Cycling on the bottom-most, high cycle-rate hardware host layer is isolated by the Board Support Package Layer, while the resource controller isolates application programs -- potentially also high cycle rate components -- from each other and the rest of the stack. The isolation cuts both ways: not only can the high-cycle rate components cycle frequently, but the medium-cycle rate operating system and its language can also evolve without overly impacting the hardware and application layers. With this high modularity, the overall processing architecture can also evolve as subsystems repartition over time -- as is occurring with radar signal processing. Diverse functions can share processing resources, accruing benefits of integrated processing while maintaining much of the attractive isolation of federated schemes.

Similarly, the graphic to the right suggests a modular hardware configuration facilitating high isolation, avionics evolution, and commercial economies. This scheme consolidates avionics in a few central enclosures as is done on the F-22, but with standard commercial backplane and board interfaces. Enclosures are connected by standard transmission interfaces. Processors can be shared or dedicated. With standard commercial board interfaces, subsystems can repartition and on-board technology can evolve without impacting other functions. Board counts can change and slots can be reassigned. New interconnects, such as fiber, can be overlaid as needed. The infrequent evolution of the backplane and board interfaces can be approached more as a repackaging problem than a major block change.

Such an architecture allows underlying system components to be decoupled and able to cycle at their natural rate. Only by adopting such architectures will major systems be able to stay viable throughout their acquisition and operational lifetimes.

Configuring Systems for High-Cycle-Rates Components

- High cycle-rate items are mostly electronics
- Most DoD electronics can be readily configured for good commercial OS Processes
  - Isolating commercial elements from platform environment preferable to MILSPEC hardening *(ex: already have commercial boards on tactical vehicles, surveillance aircraft, subs)*
  - Permits frequent technology refresh to preserve suppliers, relieve problems, reduce costs
  - Need good F^3I at enclosure and board level
  - Well partitioned functions enable asynchronous evolution, modernization through spares
  - Subsystems can even be rearchitected *(ex. repartitioning signal and data processing)*
  - Suppliers can refresh boards as needed; minimum platform and subsystem impact
  - Commercial standards -- offer most benefits, but works even when unique *(ex. tac missiles)*
- Apply philosophy on a broad scale in other domains*(ex. electro-mechanical, power supplies)*

Axiom
Manage enclosures as F^3I sockets, not as frozen configuration items; Let board configurations cycle as needed within the F^3I standard to accommodate rearchitecting and high cycle-rate components

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Although many areas of technology are cycling much faster now than in the past, the effect is seen most profoundly in electronics systems. In the past, DoD insisted on MIL-SPEC components that had to operate over a wide range of environmental conditions. Most commercial components will not meet the MIL-SPEC conditions. Two approaches can be taken to solving this problem. The first is to make sure that our specifications reflect that actual conditions that will be seen. The second is to isolate the commercial component from the military environment through proper design of enclosures, boards, and packaging.

A well designed modular architecture will permit a strong F^3I attribute at the board and enclosure level, permitting the use of commercial items inside that isolated and controlled environment.

Well designed modularity also permits the components inside each module to cycle at their natural rate, and to be refreshed with new technology as needed. It will even be possible to rearchitect subsystems as needed without unduly affecting the overall system, provided that the F^3I socket interfaces remain under control.

Status

The OS Process Concept is New –
How Close is DoD?

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Open Systems Process Status
- Force Level -

Forces have embraced OS attributes only in *very narrow areas*
(ex: some C4ISR interoperability)
Not embraced as a broad *enabler*, even in areas of seemingly equal importance
(ex: interoperability of logistics management processes)

- OS Process for JV2010
  - Impelling grass root initiatives *(ex. Pacific Fleet Command ships)*
  - Do not see substantive funding of real projects within U.S., nor within allies and coalition partners
    - Joint planning, deployment, battle management, engagement, sustainment
    - Time to first significant FTX longer than WW II
  - Joint capabilities accepted at personal level, but don't compete in Service budgets
- OS Process in general
  - Not cornerstone of vision for long-range viability and effectiveness
    - Minimal requirements, plans, investment, metrics, training, etc.
  - Minimal Service commitment; not seen as high-leverage solution
    - Perceived very narrowly -- fix specific problems; minimum initial cost, performance
- Weak follow-through on current policies and directives; few penalties for non-compliance
- Services activities are generally unique (Title 10 prerogatives)

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One would expect our forces to be able to interoperate in all important domains, as envisioned by JV2010. Unfortunately, there is precious little increase in emphasis or funding for OS attributes as a result of *Joint Vision 2010* and the Service equivalents.

Backfitting interoperability into legacy systems is an exasperating and sometimes expensive enterprise, and legacy upgrades compete poorly against new systems in Service budgets. Nevertheless, the Army has shown that it can be done even within a Service budget, and the Army has been enhanced by these efforts. That experience has not been generalized across DoD.

There has been some modest progress in the narrow areas of joint C^4ISR, electronics, and computers. Extension of the JTA concept to other domains such as logistics visibility and management systems is painfully slow. The Services are doing somewhat better internally but these efforts are often unique (Title 10 prerogatives) and do not necessarily lead to increased ability to integrate composite force elements as needed.

It is instructive that achieving a truly interoperable JTA has been such a struggle. DoD clearly has not yet arrived at a common objective or agreement on a general approach. For example, the Air Force sees the JTA as strictly limited to information interoperability, while the Army argues to include affordability and commonality measures. Clearly topics like affordability and commonality need to be significantly addressed one way or another or the investment foundation of the evolving warfighting visions will not materialize.

The OSTF does not expect to see significant progress at the force level until the ability to genuinely integrate force elements becomes a major DoD priority.

Open Systems Process Status
- Force Level (cont.) -

- Little management attention to exploiting OS to meet challenges
  - Few plans (OS Process not internalized or incorporated into daily processes)
  - Few metrics (no means to evaluate cost savings)
  - Little training
  - Little investment
  - Inadequate follow through on current policies and directives
  - Few penalties for non-compliance
- The Services are not currently committed to OS

•Acceptance of OS is through Commitment
- **Active leadership**
- **Emphasis on people and training**
- **Participation in standards organizations**

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By any of the measures one would use to judge the degree of institutionalization of a concept or process, OS is still in the introductory stage. Plans are currently scarce and weak. Even in the case of requirement plans such as Transition Planning, compliance and quality has been checkered. Few metrics are in place and far less training. The OSD OS-JTF has done well to supply materials such as a CD-ROM Desk Reference to the acquisition community but, for example, the subject is not taught at the Defense Systems Management College (which, admittedly, has a glut of topics to teach in a short academic period).

While there are exciting projects in the Services achieving astounding results, these examples cannot be generalized to the overall state of affairs. Taken as a whole, it would be difficult to argue that the Services are committed to an aggressive OS approach.

Open Systems Process *Status*

- Acquisition and Support -

- **Potential is staggering; exciting initiatives underway**
  - OS-JTF & DARPA pilot programs, Joint AeroCommanders' Group F^3I
  - Cross-system work (F-15//F/A-18//AV-8B; Sub Combat System)
- **But generally, DoD doing poorly**
  - Not yet truly embraced by Services or most Program Offices
  - Don't yet have a unifying concept; hampers institutionalizing process
  - Hobbled by
    - Inadequate appreciation of the benefits of an OS Process
    - Poor plans, processes, training, funding flexibility, metrics, compliance with policies & directives
    - Rigid statutes, policies, bureaucracy
    - Inadequate top-down emphasis and structured incentives
  - The fundamental problems are common across new and legacy systems alike
  - Legacy systems and sustainment are particularly disadvantaged
    - Crippled by old architectures
    - Legacy upgrades compete poorly in current budget crunch
    - Absence $$$, little progress likely

OS could have massive benefits, but OS Process has not really arrived;
Our management processes are crippling, self-inflicted barriers

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It is irrefutable that an OS Process can turn around systems and save missions. There are massive benefits to be gained. While specific pilot programs are turning in exciting results, it is fair to say that DoD is poor to abysmal in truly embracing OS attributes in acquisition and support programs.

Although submittal of OS Implementation Plans has been directed upon the Services, the resulting plans generally have been found to be of poor quality, and compliance with the plans has been checkered at best. However, there are DoD organizations, programs, and contractors pursuing various benefits of OS and related elements such as COTS products, commercial items, and commonality. Although we found increasing local enthusiasm for OS and commercial products, we didn't find a well structured program.

The Dec 1997 OS-JTF survey of 552 program office personnel representing 232 weapons systems programs across DoD found that most respondents were aware of OS and its advantages, but that the majority of program offices do not have a written process or procedure for implementing OS policy. The level of awareness was thought to be less in related activities such as requirements and logistics. Technical impediments were reported by 70% of the respondents; 65% reported significant institutional and cultural barriers. Most of the problems reported were common among new and legacy systems and were compounded by such factors as lack of training, absence of real incentives, and budget deficiencies and inflexibility.

The OSTF explored the issue of supportability in terms of the relationship between OS and the vision of focused logistics as expressed in *Joint Vision 2010* and supporting service documents. We found a number of government agencies and contractors who touched on various benefits of OS architecture and elements related to OS architecture such as COTS products and commonality. Although we found enthusiasm for OS and commercial products, we didn't find a well-structured set of guiding principles supporting facts about the impact of OS on achieving the goals of focused logistics.

The core problem, we believe, is that OS are not truly embraced by the leadership. While there are encouraging exceptions, there is generally a lack of leadership commitment, understanding, and incentives; and the disincentives are monumental. Leadership is crucial in that successful implementation requires a series of champions throughout the line of command. A unifying concept OS Process is probably essential for addressing these problems.

It is clear that most of the identified problems are common across new and legacy systems; and, from a process perspective, so are the solutions. But legacy systems are particularly hampered by budget deficiencies. As the overall defense budget has become more stressed, and as investment accounts are increasingly the bill payers for other priorities, the Services have chosen to focus the meager remaining funding on protecting their highest priority new programs in the current budget year. A result is a dearth of funding for upgrading legacy systems.

Numerous studies have concluded that significant efficiencies in the sustainment accounts, such as offered by the OS Process, would free up significant funding for new systems -- even after paying the up-front development necessary for the upgrades -- allowing more funds to go for modernization. Funding for such upgrades has not been forthcoming as the Services continue to focus on current year problems. Some modest improvements are being pursued with such laudatory initiatives as the Army's "Modernization Through Spares." But without funding for rearchitecting and upgrading, significant improvement will not be possible.

Revamping Program Management and Oversight Processes

Revamping Processes and Tools

The reengineering of DoD processes and tools is itself a systems engineering task -- Need an integrated approach to the whole program management and oversight process

- Mindset and Core Values, Behavior
- Requirements
- Program Management
- Specifications and Contracting
- Test and Evaluation
- Funding

Need to cover all elements of the system life cycle

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For decades the development, test, support, and oversight of DoD system has been organized around a concept of baselining to a "final configuration" and stoutly resisting change, a kind of freeze-and-build siege mentality. This "final configuration" mindset is institutionalized in program management education and practice, the structure of critical tools such as cost analysis models, the formal system development process, our philosophy of test, support concepts, and milestone review and oversight criteria. The "final configuration" perspective is a pervasive consistency and an entrenched core value.

This historic DoD "final configuration" perspective needs to be replaced with the new OS Process concepts of pervasive, architecture-driven modularity, life long system viability, and management processes which nurture change.

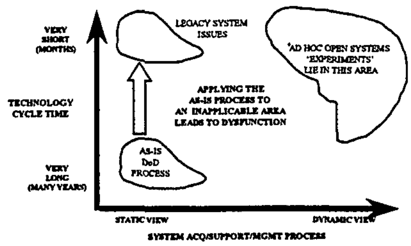
This is a major redirection of the very mindset and culture of the government/Industry acquisition community. The needed process changes cannot be achieved by merely nibbling around the edges. An integrated, systematic revamping is needed, lest the individual function operate at cross purposes.

Principal needs begin with demanding the OS attributes in the Requirements process, institutionalizing enabling program management approaches, source selection and contracting, a new test and evaluation philosophy, and the entire acquisition infrastructure from the Hill and OMB through OSD and the Services to the Materiel Commands; and the management tools provided and imposed upon program managers. Key areas are addressed in the following charts and specific remedial actions are recommended.

Revamping the Management and Oversight Process

- Changing the Way We Think and Do Business -

- Traditional Program Manager's mantra: Change is an enemy
  "Baseline to point solutions; shoot anyone who wants to change anything"
- Static solutions to dynamic world
  - Freeze and develop,
  - Freeze and test,
  - Freeze and produce



- **Traditional way doesn't work any more ... the world *is* change**

The process conflict arises from greatly shortened technology cycle times

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The existing DoD processes for systems acquisition derives from an essentially static view of technology, external demands, and system configurations. The historic framework assumed that change was largely elective and the result of a DoD-controlled process -- an Engineering Change Proposal, for example. This static view permeates the requirements community, the FAR, the acquisition process, and review and oversight at all levels. It is reflected in detail-based design review exit criteria, delivery of detailed specifications and build-to-print drawings, physical configuration audits, maintaining, government-approved parts lists, and so on. DoD-based support concepts were even less agile.

While numerous acquisition reform efforts have had some success at streamlining this process, the cycle time revolution in electronics technology has rendered this static model obsolete and dysfunctional. Today, the technology available at design time may be obsolete and unavailable at reasonable prices when it is time to build qualification articles, and again at the time of building the IOT&E articles, and yet again for initial production, and the cycle continues throughout the fielded life of the system. Simply put, the technology cycle time is inside the response loop of the classical DoD process.

The prevailing DoD situation is illustrated by the graphic above which plots technology cycle time against the agility of the acquisition system. Currently DoD tends to operate near the origin with a static-oriented acquisition approach that presumes a relatively static technology cycle rate. Legacy systems, configured according to the more static model, are caught in a high cycle rate world and fare poorly. The objective is to move to the upper right hand corner with responsive acquisition and support processes.

Requirements

- Demanding OS Attributes as Mission Critical -

- When challenging dead end architectures and technologies, a frequent reply is: "...under intense scrutiny, absolute requirement to minimize cost and risk"
- Severely disincentivizes investment beyond the minimum immediate need -- all potential outcomes for Program Manager are downside, little upside reward:
  - "We have dead-end, stovepipe systems because we disincent anything more"
  - The most powerful incentive for the OS Process is to correct the disincentives
- Requirements need to demand:
  - Plug & Fight/Play in favor of the last increment of individual performance
  - Configurations which will be viable in the long run, staying abreast of:
    - Evolving force and operational needs
    - Realities of budget, technology, and supplier availability
  - Robust migration path
- Facilitate reuse of new work by others (documentation, transfer assistance, etc.)

Requirements need to demand:

- OS Process attributes of Plug & Fight/Play and COTS affordability
- System configurations and robust migration plans for life long viability

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The traditional requirements process needs to be changed to recognize the operational imperative of Open Systems attributes. If the OSTF is correct and future operational concepts cannot be achieved absent a rigorous Open Systems Process, then the OS Process is not just an acquisition issue.

The recommended OS attributes are so vital as to be mission critical.

The operational community cannot, given the current and projected low budgets, afford to have investment funds spent which do not return a quantum increase in operational effectiveness. In the current environment the ability to innovate and integrate forces as needed at the moment, and the capacity of systems to stay viable, is operationally more important than the last increment of individual performance.

When the continued use of dead-end, stovepiped architectures and technologies is challenged, a frequent response is that the requirements demand nothing more. Most Program Managers are severely disincentivized against incurring cost or schedule risk for anything more then the minimum immediate requirement, and there is little or no upside reward for enabling long-term viability. Today, obsolescence, difficulties integrating with the force, and unaffordability are more effective threats to systems than enemy action.

By the nature of the DoD acquisition process, this situation can not be significantly corrected without a requirements demand for the OS Process attributes. Requirements must demand the benefits of Plug & Fight/Play, COTS affordability, and system configurations and robust migration plans to enable long-term system viability.

The operations community is stuck with dead-end, stovepiped systems which are support nightmares and risk critical missions because, in part, the formal requirements process demand little more than that.

Core Mindset for Program Management

- OS Process Must Permeate Whole Structure -

- At the Program level, OS Process will become a survival core value
- System solutions start with understanding the problem to be solved
  - System definition phase must include a Viability Risk Analysis and required interfaces with related architectures
  - OS-compatible analysis tools should be accessed -- partitioning, cost, technology and obsolescence projection, etc.
- Architecture-driven modularity developed in system engineering process enables Plug & Play HW and SW, and reuse -- *minimizes constant regression testing*
- OS Process attributes and robust migration plans demonstrated in System Concept Definition and intergrated into Performance Specifications
- Management processes nurture natural cycle rates of components and interfaces
- Enabling Program Management infrastructure also demonstrated; for example:
  - Acquisition plan, review processes, and criteria
  - Architectural Control Board (ACB) and compliant architecture hierarchy
  - Contracting and Source Selection criteria
  - Test, product support, training
  - Diminishing supplier program

Must permeate entire acquisition management processes, Source Selection criteria, and milestone and upgrade reviews

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OS Process attributes are rapidly becoming requisite for the survival of programs. Programmatic threats were discussed in the viability risk analysis. Given the current era and the worsening budget environment, many programs are a higher risk from programmatic actions than from enemy action. An OS Process must permeate DoD management processes, Source Selection criteria, and formal Milestone and upgrade reviews.

With increasingly prolonged acquisition cycles, technology is often obsolete several generations before EMD is complete, much less before fielding of the weapons system. The result is increased cost and time to mitigate the effects of technology and parts obsolescence. The operating efficiency of the rest of the force structure is often jeopardized, and fielding is even later than planned -- often due to attempts to avoid rising costs on a near term basis -- by stretching the development program.

An OS Process brings with it other characteristics to provide program management tools and to mitigate the pitfalls of business as usual. These are:

(1) Robust mitigation plans to keep the technology and design fresh, providing a matrix of anticipated changes and resulting configurations referenced to program milestones;

(2) Early commitment and demonstration to the foundations and definition of the architecture, modularity, and flexibility;

(3) Formal processes for forecasting change and synchronizing likely high cycle rates with other change cycle levels for remaining tiers of the weapons system, and for temporally pegging them to program milestones reviews;

(4) Modification of normal definition of exit criteria at CDR, PDR, or any program milestones reviews to reflect the upgrade or refresh plan, based upon maintaining Form, Fit, Function, and Interface (F^3I) discipline.

(5) Use of an Architecture Control Board process to ensure compliance and conformance; and

(6) Make OS attributes a primary Source Selection criteria.

The entire program management process needs to be reengineered as a coordinated asynchronous flow, geared toward the most rapid technology turn cycle (also may be considered the obsolescence cycle) across the full life of the program: requirements definition, development, T&E, production, and support. System level specification need to be functional as in the Performance Based Business Environment. Formal definition of exit criteria for key program milestones such as PDR and CDR should be modified to reflect an F^3I structure and Migration Plan.

Contracting and Source Selection

- Encourage OS Processes -

- Revamp the FAR
  - Natural extension of Performance Based Business Environment (PBBE) already started
  - Eliminate regulated obstacles to OS Process
  - Impose architectural hierarchy and ACBs
  - Align contract structure with system architecture (development through support)
  - Make OS Process a required Source Selection Criteria
- Reorient Specifications and Interface Control Documents
  - Specify and baseline system-level functionality (PBBE) and FI (OS) interface control
  - Manage high cycle-rate functions to FI and mitigation plans
    - Contractors and suppliers have lower tier configuration control within FI discipline
    - Abandon build-to-print process in favor of interface specifications
    - Contractors analyze best use of resources across all criteria
      - Implement program and migration plans by most economical process
      - Focus on best system/component/part value
      - Freedom to innovate using competitive pricing
    - Minimizes Class I changes
- Strong OS Process treatment in Source Selection

Force OS Process to become an industrial base core competency

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The FAR, a product of the historic static perspective of the world, presents a number of impediments to an OS Process and, not surprisingly, does not capture opportunities to be constructive in this context. Renovation is underway to implement PBBE, an underlying assumption of the suggested OS Process.

The PBBE-like renovation should be extended to put into place some of the foundations of an effective OS Process and remove impediments. Example measures include recognition of the necessity for a hierarchy of architectures and accompanying Architectural Control Boards, and establishment of an interlocked hierarchy between the Government Program Office, Prime Contractor, Subcontractors and Suppliers. The FAR should recognize that contract structures need to be aligned with the structure of the system architectural hierarchy. The necessity for tailored management of high-cycle rate elements would be reflected in system definition and baselining in terms of functional PBBE-based specifications, the system architecture, and F^3I interface control documents controlled by the hierarchy of ACBs, and mitigation plans to assure and enable life-long system viability. Review and oversight criteria organized around the build-to-print perspective would be abandoned.

The hierarchical ACB structure is essential to maintain F^3I discipline while passing control of lower tier detailed configurations to contractors and suppliers. This approach offers the potential for increased competition at each lower tier, significant cost and schedule improvement, refreshed technology, and a continuing supplier base.

The ability of the government and contractors to implement migration plans, seek the most economical processes, focus on best value, and have the freedom to innovate using competitive prices is all enhanced. Properly constructed, this approach appears to offer the ability to dramatically reduce the need for Class I changes to the weapon system and the attendant requal costs. However, the prOS Processective gains can be foiled by trying to accomplish the objectives without addressing cultural changes in the acquisition and test communities.

Test and Evaluation

- New Philosophy: Validate Functional Performance and F³I Provisions -

Many interviewees consider current test practice a crippling OS Process impediment

- Test philosophy must acknowledge that configurations are temporal -- they *cannot* pre-exist or endure
  - IOC configuration cannot pre-exist at OPEVAL
  - OPEVAL configuration cannot pre-exist at qual test
  - Configurations probably not even constant across test units
  - Product support must deal with continually evolving configurations
- Early functional testing may have to use surrogate hosts
- Must reengineer test flow to test functionality, F³I, and migration path early, then balance other test needs with reality of evolving product configurations
- Avoid full duplication of tests between configurations, contractor, government (ex. Software regression testing is usually very expensive and often unnecessarily duplicative)
- Testing must be tailored to the phase of evolution of the product requirements

**Must revamp test objectives, philosophy, criteria;
Need demonstration programs**

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IOT&E was frequently cited as an major OS Process stumbling block.

The basic philosophy of weapon systems testing must be revamped. Current focus is on validating the "final configuration" which will go to production. Test philosophy needs to acknowledge that the natural cycle rate of some technologies is less than the test period and certainly less than the time from design to initial production. In many cases, components which should be used in production will not have been invented yet at the time fabrication starts on the OT&E test articles. Clearly it is time to rethink DoD test objectives, philosophy, and test planning.

Today the factors most important for weapon system effectiveness are functional capabilities and the ability to stay viable by many criteria. So this is what testing should validate. Early testing should focus upon operational and support functionality, the robustness of the architecture-driven modularity, and long-term migration planning. As the design matures, testing should address the adequacy of the F³I specifications and the expected implementation of the interfacing assemblies. While the current implementation of an assembly may be tested to help assess the adequacy of a F³I specification at the system level, it is more the specification which is being validated rather than the particular implementation of the assembly. Assuring assembly compliance with the F³I specification is usually not a system level test issue.

If quality modularity and reuse is achieved, then duplicative testing should be addressed -- particularly software regression testing, which is currently enormously expensive for DoD.

Since legacy systems are particularly a problem, the OSTF suggests a series of demonstration projects be conducted, using legacy systems that are candidate for technology refresh, to help develop a revised test policy. Emphasis should be on three issues: 1) how to synchronize technology insertion and functional testing; 2) reductions in test personnel and time allocations; and, 3) metrics to capture the cost savings for both insertion and testing.

Funding

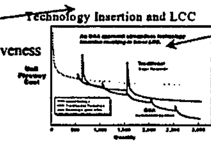
- Current Practice Causing Serious Difficulties -

- Maintaining system viability requires overall life cycle Responsibility, Authorities, and Accountabilities (RAA)
  - PMs generally have life cycle responsibilities, but neither authorities nor resources
  - Let PMs balance the pain between NRE and recurring O&M
  - Assign PM's total life cycle RAA
- Colors-of-Money (RDT&E vs. Production vs. O&S) inhibit effective technology renewal
  - For high-cycle-rate elements, problems and their solutions extend across color boundaries
  - Support problems just as bad in R&D and Production phases
  - Need relief to allow technology renewal with any color-of-$$ available

Current Practice
Major drop in capability
Large mods hard to fund

Technology Insertion and LCC

Sys Effectiveness



Sys Effectiveness

Open Systems Process
Retain capability
Changes easier to fund
Some don't require govt $$

- Funding need changes are very difficult for most programs
  - Changes mostly accumulate until major system upgrades; often involve expensive platform mod
  - Changes plus mod cost difficult to fund; jeopardizes program
  - OS Process could spread changes, avoid many mods; funding more likely

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OS attributes usually reduce costs for all phases of programs, and can be readily included in new systems. In the new, high technology turnover work, the restrictions accompanying distinctions between the various program phases are dysfunctional to the point of crippling programs. The full life cycle needs to be managed as an integrated whole. For the most part, program managers have such responsibility, but insufficient authority and resources. Program managers need to be vested with the full authorities and unfettered resources necessary to seamlessly manage the system life cycle.

Current color-of-money restrictions are enormously crippling. This situation has been the subject of the DSB and DoD work and is well understood. Color-of-money restrictions will also significantly impede OS attributes, further adding to the urgent need for correction.

While defense funding overall has declined, operations, support, and modernization costs continue to mount. Forces are reduced and the investment accounts are often billpayers, further reducing modernization. As systems and parts rapidly become obsolete, they need to be upgraded to stay viable. But because of the lack of F^3I compatibility -- hardware to hardware, software to software, and hardware to software -- the ability to change by simply upgrading the technology without making major changes to the weapon system is virtually non-existent. The cost -- using today's culture and testing "rice bowl" mentality -- is often prohibitive and the budget often unavailable. Absent architecture-driven modularity, components, assemblies, and subsystem -- displays, comms, processing -- must often be extensively modified and requalified. A major mod cycle is required. As a result, needed subsystem upgrades accumulate, more components become obsolete, and the system rapidly loses viability, putting the operational mission in jeopardy. This downward spiral is being replicated throughout DoD.

Incorporation of an OS Process can provide major relief for this situation, if considered early enough in the process, and if combined with an plan to incorporate technology in frequent and timely reasonable increments, compatible with F^3I discipline. With good architecture-driven modularity, components, assemblies, and subsystems are effectively isolated from each other and can be refreshed at their natural rates. A mod cycle can be modest, if needed at all. Upgrades can be inserted as they are available, funding strangulation can be avoided, and systems can remain significantly more viable in all dimensions: operations, funding, technology currency, and mission effectiveness. DoD's continued reliance on legacy systems becomes considerably more feasible.

Infrastructure Needs

- Tools for program planning, cost modeling, budgeting, sustainment
  - Planning tools incorporating high cycle effects and OS effects are immature
  - Couldn't find cost estimating tools -- some being started
- Acquisition processes need to be reengineered from PDRR through Support
  - Strong disciplined systems engineering essential; grow competency by multiples
  - Decrease component design and test engineering
  - Develop management and integration techniques to marry low cycle change elements with high cycle change elements later in process
  - Confirm HW & SW structure very early -- before application development
  - New functional validation and design review exit criteria
  - Test philosophy: Minimize duplication, qualify SW early, qualify HW late, update SW always
- Currently training is very limited
  - Not a curriculum topic in DoD professional schools
  - Acquisition and logistics workforce not trained to PBBE and OS Process
  - Functional and interface discipline vs. "how-to" and "build-to-print" specs

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Three major elements of the infrastructure need to be addressed to facilitate incorporation of an OS Process: Financial and Planning tools, the Acquisition Process itself, and Training. Cost modeling and budgeting tools need to be addressed for functional requirements and life cycle effects. Cost estimating relationships are virtually non-existent when viewed in the context of the significant process changes advocated, covering development, test and evaluation, incorporation into product, and sustainment. In the same vein, planning tools need to be developed, along with the cost relationships, considering high cycle-rate technology introduction using the rubric of F^3I. For the life cycle, tools need to be developed to quantify the advantages of frequent technology renewal by the OEM instead of continuing build-to-print of obsolete parts.

The Acquisition Process needs to be reengineered from development through sustainment in order to take advantage of the anticipated saving offered by incorporation of an OS Process. F^3I and substantial changes from traditional configuration management are critical to successful implementation of the OS Process. This creates a demand for strong, disciplined systems engineering. As a consequence, systems engineering needs are projected to grow by multiples, while detailed design engineering needs should decrease by greater multiples. An OS modular and portability concept needs to be institutionalized, including the synchronization of changes from high cycle-rate technology turnover. COTS approaches for software development must be included. Configuration definition needs to account for those elements likely to remain stable over the life cycle and those subject to frequent change. Functional validation and design review exit criteria need to be established accordingly, along with a test and evaluation philosophy reflecting definition of a temporal, rather than a final, configuration.

There is a significant shortfall of personnel in the acquisition workforce and logistics infrastructure who are trained in the PBBE and the OS environments. Yet, it is these two groups who are perhaps the most critical to successful implementation and can prove to be the greatest impediment to success.

Industrial Base

DoD-centric analysis argues strongly for imposing extensive OS requirements – need to consider impact on industrial base

- Business basics require that investment be recovered and profit made
- Impact of imposing OS requirements on industry
  - OS greatly reduces non-recurring and recurring cost, which equals less profit/win
  - Few new starts and upgrades = less wins
  - OS reduces barrier-to-entry; harder to assure future business
  - Incentive for unique investment drastically reduced
  - Primes significantly disincentivized for OS Process unless business is at severe risk
- Lower tiers greater than ~ 75% systems cost
  - Face primes' problems + primes vertically integrating and influencing buy decisions
  - Lower tier unstable; caught between economics of DoD, primes, and commercial
  - Much OS use in the lower tiers
- Pressures are driving DoD to become more involved in the lower tiers

Industry will follow if necessary, but not their choice – Recommend that DoD cause a detailed investigation of lower tier market dynamics and economics

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The urgent needs of DoD and the potential enormous benefits of OS argue strongly for extensive adoption of an OS Process. The OSTF has some observations concerning the impact on the defense industrial base, a cornerstone of any implementation of an OS Process.

The fundamentals of business in the U.S. require that investments be recovered and profits be made. Our system is generally self-enforcing -- inadequate performers eventually fail.

In the commercial market, Openness generally fosters overall market growth and permits minority player participation. For example, accessible operating system interfaces have enabled a vast application program industry, which in turn has fostered an overall PC market which is many orders of magnitude larger than would have occurred without Open interfaces. It is instructive to note that major firms like Microsoft depended heavily on Openness for initial market entry and then, once established, adopted more restrictive strategies.

The "market growth" dynamic does not generally exist in today's defense market: the total DoD budget is essentially fixed and there is little opportunity for the industrial base to influence the allocation between investment and the other accounts; there are few new starts. In aggregate, these dynamics create in large incumbent contractors a massive disincentive to change the status quo. They will see as the primary effect of OS the spreading of the limited funds across even more contractors, which will reduce margins and earnings. For these contractors, significant incentive to adopt an OS Process exists only when a program is at great risk, particularly if unaffordable. (IEWCS, JSF, and perhaps the BSY-2 replacement are good examples -- conventional approaches could not have been funded in the current budget environment.)

Non-incumbent contractors may be more receptive to the OS Process, since OS Processes can lower barriers to entry and offer increased opportunities.

These are probably the central dynamics behind the OS successes which we have seen in DoD. Profitability is down compared to a conventional approach, but a lower profit program is apparently better than no program.

This dynamic arguably serves both the industrial base and DoD well. Programs based on OS Processes are alive, healthy, and well postured for an uncertain future; and the industrial base is sustained. The summary of the Lockheed Martin Navy Systems Program Office in Manassas after aggressively adopting an OS approach to the BSY-2 replacement is instructive. Good as their traditional products were, they were unaffordable in the current budget environment and the business was in extremis. The Program Office took the controversial approach of organizing around an OS strategy and now feel that they have the best system in the world. Apparently their U.S. and allied customers agree, for their win rate has been unprecedented. But they feel competitively vulnerable with the OS architecture and continue to strive aggressively to offer customers the very best value. They have done as well in the new budget environment as they could have and they are healthy. This seems a noteworthy model for the future and well worth pursuing.

The situation at the lower tiers, representing about 75% of system cost, is more complex and only marginally stable. They face most of the problems of the primes and, additionally, are caught in a pinch between consolidating primes who are also becoming more vertically integrated, and the expanding use of COTS. There is increasing concern for maintaining genuine competition and a viable industrial base. Some of the most extensive use of OS approaches occurs in the lower tiers and that can only increase.

Pressures are driving DoD to become more involved in the lower tiers of the defense industrial base. The OSTF recommends that DoD cause a detailed investigation of lower tier market dynamics and economics to occur.

Pilot Program Candidates

There are several programs which would be good candidates to be designated pilot programs for pathfinding implementation of an OS Process:

- National Missile Defense
  - Mission is to achieve and maintain a deployment ready posture until a deployment decision is made, with continuous rolling technology insertion program
  - Largely a System-of-Systems, dependent upon other, evolving systems not subordinate to the program office; dependent upon an architecture-driven modularity approach; long-term viability will be a particular problem
  - Newly appointed Lead System Integrator with good OS perspective and implementation capabilities; good chance of OS Process success
- Theater Air and Missile Defense
  - Mission is to establish and maintain interoperability between a host of service surveillance, battle management, and weapons programs to achieve an integrated trans-DoD capability
  - Almost entirely a System-of-Systems, dependent upon other, evolving systems non-subordinate to the program office; dependent upon an architecture-driven modularity approach
  - Requirements and CONOPS responsibility rest with JTAMDO and engineering with BMDO. Lead system engineering responsibility for implementation not yet established. Excellent application of OS Process early enough in process
- Joint Tactical Radio
  - Excellent front-end effort but no real implementation program yet; would be an excellent application of an OS Process early enough in process

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USD(A&T) should designate several major programs with extraordinary need for OS attributes as pathfinder programs for implementing the OS Process. Candidate programs include NMD, JTAMD and JTRS. These pathfinders are supportive of JV2010 and should immediately provide a significant driving force for launching the OS Process as the preferred method of systems acquisition. The business case for selecting these programs as OS Process pathfinder programs is based on the following reasons:

(1) Interoperability and Dominant Maneuver: Continuous, uninterrupted flow and processing of information among the many fundamental building blocks (e.g., Ground Based Interceptor, Space-Based Infrared Systems, THAAD Battery, and Wide-band Networked Radios) of these sophisticated systems is essential for dominant maneuver, real time, and effective operations. Adherence to Open standards is needed to achieve interoperability among systems and subsystems comprising each of these pathfinder systems.

(2) Integratability: No single system can perform the entire JTAMD or NMD mission. There is a strong need for a system-of-systems approach to achieve integratability of lower and upper tier systems, and integration of joint Forces to exploit land, sea, and air combat capabilities. The JTRS will also require integratability at different Force levels, and integration within and among Services and allies.

(3) Long-Term Viability: The strong dependence on state-of-the-art technologies by these systems demands flexibility to respond to evolving and more advanced threats, and the capability to rapidly insert new technology in real and near real time. As the key nugget of the OS Process, architecture-driven modularity is the best guarantee for access to latest commercial technology and continuous viability of these systems.

(4) Affordability and Supportability: These pathfinder programs lend themselves to the architecture-driven modularity, software reuse and portability, and hardware commonality features of OS. These features are essential for creating economies of scale to minimize operations and support costs, facilitate repair and maintenance, and ensure access to multiple sources of supplies throughout the entire life cycle of each system. DoD must leverage the investment made by other federal agencies and the commercial industry in technology, products, and processes relevant to these systems to reduce the total ownership cost and maximize supportability of each system.

Incentives and Disincentives

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OS Process Implementation Challenges

Should Be Easy	Will be Tough

OS Process is a mindset for architecting
• We already architect Forces, systems, and processes
• We already use configuration control processes
• OS Process is just an additional criteria
• There are industry and DoD role models
• Some programs motivated as survival issue: "cheaper, better, faster" can save programs
• We should be doing it anyhow
	Our processes are dysfunctional obstacles
	• Geared for static programs in a static world
	  • "Freeze & build"
	• Phobic to managing change; ex:
	  • Budgeting criteria
	  • Acquisition milestones
	  • Parts/technology refresh $$

Implementing OS Process is an institutional matter

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The challenge of implementing an OS Process is not so much about technology as it is about influencing the program managers and other acquisition practitioners to think in terms of configuring systems for constant evolution in a dynamic world. We already do many of the things needed to implement an OS Process such as architecting forces, systems, and processes. In addition, the realities of fiscal pressures and industry practices are moving some programs to an OS Process as a matter of survival. However, our institutional processes are holding back our program managers and other acquisition practitioners from doing what it is they should be doing anyhow. Artificial milestones, constrictive budgeting rules, and lack of support and funding for evolutionary technology refresh, are significant disincentives and barriers to managing change in an institutional process created to produce static programs for a static world that bears no resemblance to reality. OSD and Service leaders must clearly and strongly champion Plug & Fight/Plug & Play to successfully enable our acquisition practitioners to implement an OS Process. This support by the senior leaders needs to be visible and sustained if the institutional obstacles are to be overcome.

Incentives

- We have smart people who want to do a good job; we need to ...
  - *Remove the impediments and disincentives*
  - Set objectives and boundaries
  - Include OS achievement as a specific job expectation
  - Evaluate commercial incentive practices
  - Reward OS successes
    - High visibility recognition by Leadership
  - Tolerate thoughtful mistakes
  - *Get out of the way*

Commit to removing the impediments, recognize successes,
Get out of the way

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A large majority of respondents to the OS-JTF survey regard lack of real incentives as a major obstacle to OS implementation. The DoD constituencies responsible for Plug & Fight/Play are motivated by different kinds of incentives and rewards. Some may be motivated by intrinsic rewards and incentives such as strong personal drive and achievement, and will find innovative ways to overcome to obstacles (i.e., disincentives). Others will adopt OS only when they are provided with extrinsic rewards and incentives, and only after the Services, components, or the senior DoD leadership remove the disincentives.

DoD must clarify OS Process expectations and delineate boundaries of actions for those responsible for implementation. All DoD constituencies who are in one way or another influencing decisions regarding weapons systems procurement and application, or are being impacted by the OS Process, must share a common understanding of the concept, advantages, and requirements for Plug & Fight/Play.

About one third of the respondents to the OS-JTF study reported that they are not aware of OS and do not adequately understand OS. One third of the respondents also consider OS to be a short-lived initiative. Extensive use of OS requires that all DoD constituencies become aware of the OS concept and have a shared view of OS advantages and requirements. They must reach a common conclusion that the OS Process is not another short-lived DoD initiative but a new engineering and business strategy for fielding superior warfighting capability faster and more affordably.

The job description and the criteria for performance appraisal and promotion of the acquisition workforce must also change to reflect the need for achieving Plug & Fight/Play. DoD must make achievement of OS a specific job expectation. The acquisition workforce must be required to attend Plug & Fight/Play training and be certified in OS to be qualified for promotion.

To promote effective implementation of the OS Process, DoD must provide incentives to all its constituencies including acquisition workforce and industry. Industry plays a vital role in building adaptable technical architectures and will build flexibility into systems if the requirements call for it and proper incentives are provided for doing so. DoD must model commercial practices in motivation and distribution of rewards. Creativity and receptiveness to change must be encouraged and thoughtful mistakes and failures tolerated. We must publicize OS success stories, establish an OS-based incentive system, and give awards for excellence in OS application. Few people are able to continue a pattern of achievement and success without the added encouragement provided by senior leaders recognizing their achievements.

We must also remove the layers of bureaucracy that do not add value to the OS process. DoD organization structure is heavily layered and staff elements are highly populated. In order for each element of each layer to justify its existence, they add content, debate, and delay to program execution. Guidance, as it flows down, is additive rather than complementary. This structure is supported by processes which are built around a short time horizon, tax dollar allocation (and reallocation ad infinitum), and management gate-keeping based on program funding content rather than risk management, capability insertion, and cost of ownership. These processes justify the jobs of a huge cadre whose expertise is in technical, legal and financial debate rather than capability delivery. In the end the systems are delivered as a result of industrial commitment to deliver to a contract, and sheer momentum.

The Most Crippling Impediments

Most barriers are self-inflicted and entrenched

- Requirements
  - We have stovepiped systems and dead-end technologies because Requirements demand nothing more *[ex: B-2 Defensive Avionics 8088 Processor -- meets requirement]*
  - If we want viable, enduring Plug & Fight/Play systems, then we need to ***require*** them
- System management philosophy -- currently "freeze and build"
  - Baselining to the wrong criteria: frozen detailed configurationsvs. F^3I "sockets"
    - Continuous technology refresh throughout entire life of system
    - Leverage supplier evolution and "cheaper, faster, better"
  - Management processes are phobic and dysfunctional in today's world *[ex. management, budget, milestone criteria, test, tools]*
- Legislation and regulation *[ex: Firewalling Dev/IOT&E/Production, Baseline Breach reporting]*
  - Color-of-money inflexibility precludes much technology refresh
  - IOT&E criteria: freezes rather than follows evolving functionality and evolving product configurations

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The Plug & Fight, Plug & Play, and OS capability requirements must become key performance characteristics for procuring and fielding systems. We have stovepiped systems and dead-end technologies because we do not consider affordability, flexibility, and upgradability to be essential system characteristics when we define our key performance requirements. Our operational performance requirements must leverage industry's technology and practices, and incorporate modularity and commonality principles to allow easy maintenance and repair.

Viable, enduring, flexible systems inherently are not compatible with a "freeze-and-build" mentality. DoD must abandon the current acquisition approach characterized by "freeze-and-build" and instead concentrate on a new acquisition philosophy typified by evolution and the ability to "leverage and adapt." To effectively meet the new threats, emphasis must shift to evolving functionality, product and force configuration

DoD must also ensure that current laws and regulations are congruent with creating a Plug & Fight/Play capability. Proper legislative and regulatory changes must be proposed to enable more flexibility in reallocating funds between the acquisition phases, and to provide additional funds for implementing the OS Process in legacy systems.

To effectively implement Plug & Fight/Play, current budget processes must become adaptable to needs and requirements of the OS Process. 80% of the respondents to an OS-JTF study of 236 weapons systems programs, representing 552 PEOs, PMs, and their staff, regard budget inflexibility as a major obstacles to OS implementation. A funding scheme more receptive to OS Processes would be the first step toward removing budget-related obstacles. The demand that all elements of a system within a particular appropriation be funded the same way works against aligning buying practices with technology cycles. How predictably one expends the program funds must not be more important than how effectively those funds are applied. DoD program lifetimes are so long that not requiring more than your allotted share of the funding pool is far more important than what value is delivered for the funds expended.

The Most Crippling Impediments (cont.)

- NIH ("Not Invented Here")
  - OS Process is vital for parochial Title 10 interest, but difficult to adapt
  - OSD sponsorship invokes suspicions, vulnerabilities, prerogatives
  - With OS Process, particularly easy to invoke usual excuses:
    - "We're already doing that"
    - "We don't need to do that"
    - "You can't make us do that (Title 10)"
- Lack of intense motivation and vigorous commitment
  - This type of change will not naturally occur -- requires aggressive leadership *[ex: AF infusion of reliability into TACAIR]*
  - Commitment at some lower DoD and industry levels for program survival *[ex: JSF, IEWCS]*
  - Senior Leadership not there yet

OS Process can be done and would have massive benefits, but the barriers preclude its wide implementation

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Aggressive leadership presence and long-term commitment is essential for effective implementation of Plug & Fight/Play. Accountability for long-term performance is completely missing in within DoD. The mentality characterized by "we're already doing that," "we don't need to do that," and "you can't make us do that," resulting from misinterpretation of USC Title 10, must be replaced by open-minded attitudes regarding change and an acquisition culture amenable to OS.

In order to fight jointly, the Services must have an interoperable system-of-systems that is based on DoD operational and systems architectures that are integratable. If each Service uses the OS Process, but each defines its own unique process for developing its operating and systems architectures, then it is unlikely that those architectures will be integratable across Services. This strongly suggests that we reevaluate USC Title 10 to be sure that there are no obstacles to the use of the OS Process to interoperable systems-of-systems.

The DoD acquisition culture is based on short-term redistribution of tax dollars rather than long term planning for the delivery, upgrade, and sustainment of military capability. Current DoD acquisition planning is a process of figuring out how to cram as many programs as possible into the available budget without breaking any of them so badly that they risk termination. This is coping rather than a modernization plan. Once a program has made it through the new start process, all of the capability increase and sustainment decisions within and across are subordinated to these fiscal considerations. As a consequence, programs are continually over-specified and under-programmed, leaving them to drift from execution crisis to execution crisis.

Another issue related to the current DoD acquisition culture is that it is a "System" culture. Program boundaries are drawn at a very high level, and the acquisition processes employed for the "System" are deemed acceptable at every level within the program. This guarantees that sub-systems baselines are frozen early and delivered late and obsolete — with virtually no consideration for the implications. The System culture has also blinded DoD to the extremely high leverage that buying below the systems level has on the DoD budget. Since there are more tax dollars redistributed below the major system level than above, and since these dollars are the under-pinning for jobs, congressional and departmental interest and support for improvements in depot/arsenal/yard operations is thin.

According to the OS-JTF survey, mentioned earlier, barriers to OS implementation indeed exist and resistance to the application of the OS process is expected. A large majority of those who responded to the survey are facing technical barriers in implementing OS. Moreover, half of the respondents feel that their job will become more difficult as a result of applying OS.

Regarding organizational (i.e., structural or cultural) barriers, a majority of the respondents to the OS-JTF survey reported facing some organizational barriers in implementing OS. A large majority of the respondents regard budget inflexibility, absence of training, lack of a defined OS implementation process, DoD culture and politics, and bureaucracy as potential obstacles to OS implementation. Additionally, they also believe that absence of real incentives, lack of awareness, conflicting policies and guidelines, no involvement in top level OS decision making, and opposition from government decision makers are potential obstacles to OS implementation. Interestingly, only about one-third of the respondents regarded opposition from the industry to be an obstacle.

Conclusions and Recommendations

Conclusions

- Open Systems Process is fundamental to many DoDpriorities that are dependent upon a process-based approach
  - JV 2010 and Service equivalents
  - Force modernization
  - Reduced cycle time and ownership costs
  - Favorable industrial base realignment

  Open Systems Process is a Warfighting and Title 10 *essential core value*
- Forces, systems, and processes need to leverage change:
  - Configure Forces, systems and processes for continuous viability
  - Achieve architecture-driven modularity
  - Manage to the natural cycle rates of underlying components
- Open Systems Process is based upon a hierarchy of architectures and standards developed with a performance-based collaborative approach
- Unlikely that DoD can implement Open Systems Process by usual bureaucratic means
  - *Open Systems Process is a cultural and budget challenge*- process is within our grasp
  - Requires support from DoD, Administration, Hill, and Industry
  - Need to reconfigure Forces, systems, and management processes
  - Removing impediments is most important

Requires aggressive leadership, SecDef and Service Secretary championing

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The OSTF finds it unimaginable that a number of DoD priorities can be achieved without a massive infusion of an OS Process and related investment to implement OS architectures.

Example priorities include:

- JV 2010 and the Service equivalents, with their high dependence upon rapid, collaborative responses with distant ad hoc forces and all the associated planning, deployment, and sustainment tasks -- all dependent upon a genuine Plug & Fight/Play capability across the Forces.

- Force Modernization, which appears largely unaffordable in a budget which is already severely constrained and, in the opinion of some, may worsen dramatically. The economies, expediencies, and ability for tech refresh of OS will be essential for programs to be sold and remain viable.

- Reduced Cycle Time and Ownership Cost, being driven in the wrong direction by recent developments such as a consolidating industrial base, uneconomic lot buys, dwindling supplier base, and program redirections. OS is a common denominator which can dramatically improve both cycle time and ownership cost by leveraging existing architectures and commercial investment and market volume.

- OS and the OS Process is not just an OSD/JCS joint thing, it is an ***Essential Core Value*** for Service Warfighting and Title 10 responsibilities.

Forces, Systems, management processes, and oversight mechanisms are too oriented toward static solutions for a static world, defying the realities of today's world. Such an orientation is a road to failure, as seen all around us in force deployment problems and programs at great risk for being no longer viable.

DoD Forces, Systems, management processes all must be re-envisioned and reconfigured as *crucibles to leverage change* so as to remain viable throughout the entire life of the Forces and Systems.

Continuous evolution can be economically and technically achieved only through extensive use of smart, architecturally-driven modularity, whereby Force and Systems are seen as a structure of F^3I "sockets" to enable the natural cycle rates of the underlying components.

Finally, DoD management and oversight processes must be revamped to enable the needed continuous evolution from requirements generation and system concept development through field logistics support. *Current processes are hostile to the needed OS measures.*

The recommended OS Process is based upon a hierarchy of architectures and their associated interface standards. A well crafted hierarchy is necessary to simultaneously achieve the benefits of Plug & Fight, Plug & Play, and the economies of commercial components. These are each unique attributes with their own sets of enabling conditions. The architectures required to achieve each attribute are different and must all be carefully coordinated or they will thwart each other.

Each architecture and the associated interface standards should be developed and maintained with a performance-based collaborative approach in which Line Authority establishes the end objectives and the stakeholders determine the "how."

Although the the basics of OS are in hand and readily understood, DoD will not achieve widespread implementation by its natural processes. OS Process is an institutional challenge. DoD must revamp a number of processes, something DoD does only with great pain. The transformation needs to include oversight processes as well and will require support from throughout DoD, the Administration, and the Hill. Industry will have a large role to play and that support should be requested.

This DoD OSTF and the OS-JTF have each concluded that that removing the impediments to OS implementation is a critical requirement. Each Task Force has identified a number of impediments and these should be explicitly attacked.

Finally, we need to reconfigure Forces, Systems, and key processes to enable continuous evolution for life-long viability.

These are radical recommendations for DoD and successful implementation will require aggressive leadership, championed by the SecDef and Service Secretaries.

Recommendations

(1) Establish Special Assistant for OS Process Implementation

(2) Take Immediate Program Actions

- Direct preliminary efforts
- Designate pilot programs

(3) Institutionalize OS Process

- Implement and mandate Open Architectures
- Revamp management processes

(4) Leadership and Championing

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Recommendations
- Establish Special Assistant for OS Process Implementation -

Appoint a Special Assistant for OS Process Implementation within immediate office of the SecDef

- **Focus on *permeating the process*, not individual solutions**
- **Normal DoD mechanisms inadequate to broadly and effectively implement an OS Process** *(ex. existing OSD Executive, Steering Group, Agency, Lead Service, etc.)*
  - Precluded by inexperience and organizational impediments, equities, prerogatives
- **Effective implementation requires empowered advocate, solid OS Process experience**
  - Provocateur, advocate, guide, expert counsel, mentor
  - Map general implementation path, recommend actions and direction
  - Executive advisor to SecDef, CJCS, and staffs
  - Implementation secretariat, staffed by OSD Open Systems Joint Task Force
- **Appointing a Special Assistant to the SecDef is markedly superior to normal mechanisms**
  - Ensures someone with considerable industry and DoDexperience
  - Probably no single individual with all the desired experience and stature, but can get close enough to jumpstart the process
  - Have identified a sample candidate from industry (DoD candidates lack sufficient industry experience)
- Could support with a USD(A&T)/VCJCS/ASD(C3I) OS Implementation Board

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The OSTF found that a major cultural change is required in the way the DoD manages and oversees systems acquisitions. Because the former culture is deeply ingrained in the workforce, the regulations, and the normal mode of business, it is believed that a Special Assistant in the immediate office of the SecDef is required to implement these changes. Significant rank and authority are needed to make the change effective and permanent. Current management structures within the DoD are too wedded to the old way of doing business.

The Special Assistant would serve as the advocate for the OS Process, and should therefore have considerable experience with OS Processes. The principal roles would include being the chief advocate, chief OS Process advisor to the senior leadership, management and technical expert, guide, counselor, provocateur, and -- when needed -- a point of disciplined strength.

The Special Assistant will head a Secretariat staffed by the present OS-JTF, augmented as required. The Secretariat will map a pathway to full implementation of the OS Process, recommend policy to senior leaders, recommend actions needed to ensure compliance with OS policies to SAE, PEO and PM officials, and issue direction as appropriate.

The Special Assistant should have considerable relevant industry experience. The OSTF does not disparage the current DoD acquisition work force, but believes that OS is sufficiently new to DoD that there are few, if any, candidates who possess the minimum range and depth of relevant experience. Industry, on the other hand, has been engaged in OS for several decades, so a suitable candidate with knowledge of both OS and DoD acquisition should be identifiable.

As an existence theorem that a suitable candidate can be found, the OSTF has identified such a person.

Recommendations
- Immediate Programs Actions -

There are some specific measures which can and should be taken immediately

- **JCS within nine months amend all MNS and ORDs to require OS Process attributes**
  - Continuing viability
  - Architecture-driven modularity
  - Configure and manage to leverage natural cycle rates of components
- **USD(A&T) within three months direct all programs to**
  - **Develop a Viability Risk Mitigation Program and adapt a preliminary formal OS Process**
  - **Conduct a Viability Risk Analysis and develop a mitigation strategy -- compliance or approved Migration Plan within 1 year**
    - Immediately implement an OS Process to develop architectures, infuse architecture-driven modularity, and capture OS attributes
    - Fully integrate OS Process results into products, management processes, acquisition actions
    - Make OS per OS Process an ***immediate*** mandatory Source Selection Criteria
    - Mandatore milestone review topic at all levels, fully compliant with approved migration plan, within earliest of either two years or two milestone reviews
    - **USD(A&T) immediately designate pathfinding OS Process major programs *(ex: NMD, TAMD, JTRS, etc.)***

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The OSTF does not want to preempt options of the proposed Special Assistant, but there are important steps which can be taken immediately to start the OS Process in current programs. Recommend that:

- Chairman JCS within six months augment all MNS and ORDs to require the OS Process attributes of continuing viability of forces and systems, architecture driven modularity, and product configurations and management processes to better accommodate the natural cycle rates of underlying components and imposed constraints.
- USD(A&T) within three months direct all programs to develop a Viability Risk Mitigation Program based upon a viability risk analysis-driven Mitigation Strategy and Migration Plan.
- Migration Plans will be submitted for approval by milestone authorities within one year.
  - Programs will stand up a preliminary formal OS Process to implement the Migration Plan. OS Process and Migration Plan results will be integrated into all products, management processes, and acquisition actions -- particularly Source Selection Criteria -- within one year.
  - Compliance with this directive will be a mandatory milestone review topic, with full compliance with the approved Migration Plan, within the earliest of either two years or two milestone reviews
  - USD(A&T) designate several major programs with extraordinary need for OS attributes as OS Process Pathfinder Programs. Candidates include National Missile Defense, Theater Air & Missile Defense, and Joint Tactical Radio System.
  - These initiatives can be taken in the near term, and would provide a significant impetus to launching the OS Process as the preferred method of systems acquisition.

Recommendations

- Institutionalize OS Process -

Mandate & fully implement needed DoD-wide interoperability architectures (example domains: C4ISR, weapons systems, M&S, logistics management systems, etc.)

- **For each designated interoperability domain, establish an Architecture Control Board and supporting structure at OSD/JCS and Service levels, and throughout subordinate levels**
- **Suggest an approach based upon classic Program Office Configuration Control Board**
  - Advisory to Line Authorities
    - Establish needed functionality
    - Establish adequacy of proposed architectures and compliance with higher-tier architectures
    - Evaluate proposed changes
    - Assure integrity of processes
    - Establish and oversee compliance mechanisms
  - OSD/JCS Architecture Control Board is additional role of existing ACC
  - Each board should be supported by genuine architects/system engineers acting in the interest of the Line Authority being advised

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The OSTF can not imagine that DoD can meet the operational, budget, acquisition and management challenges identified in this report without a broad based hierarchy of well crafted architectures along the lines it has described. Developing, implementing, and maintaining complex architectures in a difficult and demanding world is a tough problem requiring structure and discipline.

Recommend that the USD(A&T) and Chairman JCS establish the Architectural Control Board (ACB) as the formal process for administering architectures to encourage the simultaneous achievement of the often conflicting objectives of (1) Plug & Fight, (2) Plug & Play, and (3) capturing the benefits of COTS. In many cases the ACB and engineering support can be additional roles for existing bodies.

The OSTF suggests that the ACB be organized similarly to the Configuration Control Boards found in System Program Offices. The CCB is advisory to the Line Authority, the Program Manager (who is often the CCB Chairman). The power of the CCB is that the Program Manager requires that all relevant actions flow through the CCB as part of the decision staffing process -- subordinates know that cooperation and compliance are essential for milestone decisions.

ACB topics would include the functionality needed from subject architectures, adequacy of proposed architectures, and evaluating proposed architectures and related standards. It is preferred that the process of developing architectures and selecting standards be collaborative amongst the stakeholders. Experience with the ATA and JTA argue that it is necessary to start with a mandated initial architecture and to amend and grant waivers as necessary to resolve problems.

Some tiers, such as for Systems-of-Systems and the Single Integrated Air Picture, may maintain an internal architecture and ACB for management purposes, but may implement needed interface controls primarily through other mechanism such as the ACC and the JTA.

Architecting and System Engineering are demanding disciplines requiring a high level of expertise. It is essential that each ACB have very competent engineering support acting in the interest of the Line Authority.

Recommendations
- Institutionalize OS Process (cont) -

- **OSD and JCS immediately enforce existing policies or change them**
- **USD(A&T) immediately and explicitly attack each impediment identified by this OSTF and the OS-JTF survey**
- **New Special Assistant for OS Process Implementation within six months roadmap a structured effort to (1) revamp relevant management and oversight processes, (2) establish incentives, and (3) attacking impediments**
  - Example domains for revamping : requirements, cost and budget, program management, support processes, source selection, performance measures, reporting and oversight
  - Coordinate closely with other reform efforts such as Acquisition Reform & RMA
- **USD(A&T) and CJCS direct revamping per the roadmap**
  - Include with other special reform activities
  - Develop end objectives and implementation plans within 4 months of go-ahead
  - First revision of all directed processes within 1 year
- **Immediately grant interim relief for programs to start tailoring legacy program management processes for an OS Process**

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There are already policies in effect requiring elements of an OS Process (e.g. DoD 5000.2-R). Unfortunately, compliance and understanding is spotty. The OSD and JCS should enforce these policies, and provide training to assist the workforce

Serious impediments have been identified by this OSTF and the OSD OS-JTF. USD(A&T) should direct immediate action to eliminate or minimize these at all levels of DoD.

The Special Assistant should create a viable roadmap that will lead DoD to:

- Institutionalize an OS Process by revising the existing DoD management and oversight practices, and mandate an OS Process for all new acquisitions and legacy system and subsystem upgrades. It is critical to establish effective OS architectures in new acquisitions, as it is difficult to retrofit to an OS later.
- Establish incentives for program managers and contractors to aggressively exploit the OS Process as a core value.
- Attack and eliminate impediments that prevent or hamper the OS Process. The OSTF finds the institutional impediments to be the greatest block to achieving OS attributes
- Task Special Assistant to direct the revamping efforts described in the roadmap.. The roadmap, including end objectives and implementation plans, should be in place within four months of appointment, initial revisions being in place within one year with Migration Plans for full implementation.
- PEOs and program managers could implement many of the recommendations now if given the latitude to do so. USD(A&T) should grant broad enabling interim relief pending revamping of mandated procedures.

Recommendations

- Institutionalize OS Process (cont.) -

- **Establish Task Force to examine implications for industrial base, particularly 2nd and 3rd tier suppliers**
- **Establish structured process for early proactive, consistent, and constructive DoD participation in relevant industry standards bodies**
- **Revise OS-JTF role**
  - Continue current roles
  - Become Secretariat to SecDef Special Assistant for Implementation
  - Nominate more senior director with industry credentials, institutional credibility, and historical perspective on the challenges
  - Augment staff skill mix to include warfighter, program manager, engineer, logistician, cost analysis, budget, and test experience
- **Establish government/industry OS Process Coordination and Advisory Council**

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Infusion of OS Processes throughout the defense industrial base is essential, and will change the face of defense contracting. DoD has some understanding of the dynamics at the prime level; far less so at the second and third tiers. A Task Force should be established to examine the probable impacts on industry of the adoption of an OS Process.

Successful implementation of the OS Process depends on industry standards that are formalized through various standards bodies (i.e. ANSI, IEEE, SAE, etc.) Standards bodies tend to be forward thinking, incremental in their approach, and deliberative in crafting solutions which balance the many competing equities in ways acceptable to all. DoD has already reaped enormous benefits from embracing commercial standards. Past experience has demonstrated that DoD has realized even greater benefits from proactively participating in the standards bodies within the format of the bodies. Industry has proven receptive when DoD has participated in a coordinated manner, making thoughtful contributions, expressing their requirements sufficiently early in the process, and remaining flexible and constructive throughout the sometimes interminable consensus-building proceedings.

Unfortunately, DoD often participates in a catch up mode. Although there have been years of technology demonstration projects and concept development, a program doesn't become "real" until there is pending EMD. Somewhere in the transition to EMD there is a rush to try to catch up in the standards area. This approach is poorly suited to industrial consensus processes and outcomes are often predictably disappointing.

Recommend that USD(A&T) establish a recognized, disciplined, funded and well organized process for participating in these bodies at all levels necessary to ensure that its interests are met

To be effective, the Special Assistant for Implementation needs to be backed up by a well-experienced staff. Recommend that the mission of the OSD OS-JTF be expanded to serve as the Secretariat for OS Process implementation.

An effective OS Process will be complex and far reaching across DoD and the industrial base. Far grater communication and cooperation is needed. Recommend that an Advisory Council be established to provide both government and industry voice, provide advice to the Special Assistant, and encourage coordination of efforts in a neutral venue among contractors who are otherwise competitors.

Recommendations
- Leadership and Championing -

- DoD Warfighting and Title 10 capabilities on downward spiral
- ***An Open Systems Process is requisite to many DoD priorities***
- Open Systems Process is no panacea, but is **a cornerstone for all solutions, a historic endowment**
- Implementing OS Process is an institutional issue -- methodology, technology are manageable
- Time is of the essence due to need and change of administration.
- Such change comes only with aggressive leadership *[ex: AF TACAIR]*

Basically a binary choice

- Energetic and dynamic SecDef, JCS, and Service leadership could be decisive
  - ***With it, there is a chance; without it, broad implementation will not happen***
- Would require working with Mr. Cohen and Mr. Hamre to develop a strong personal commitment
- Equal commitment needed from remaining leadership

Task Force recommendations assume aggressive implementation. If DoD leadership cannot commit, then merely issuing guidance, including OS Process in ongoing reforms, and helping the system do as best it can will not be sufficient

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Capabilities laid out in *JV2010* and Service equivalents are essential to the continued viability of U.S. forces. Unfortunately, current DoD warfighting and Title 10 capabilities are already in decline as a result of the significantly shifted world situation and steep declines in the budgets. DoD cannot meet these challenges without fundamental change. While there are neither "silver bullets" nor panaceas for all problems, the OSTF argues that the OS Process is a cornerstone of the solutions that will be needed to meet our current and future challenges.

The OSTF finds that OS technology and methodology is within the grasp of DoD: the challenge that DoD faces is institutional. The old ways are ingrained and resources are scarce. The needed change will require proactive, aggressive leadership. The OSTF is concerned that there is sufficient time to implement the necessary initiative given the pending turnover of the administration.

Change, and especially significant institutional change of the magnitude of the OS Process, is impossible without strong leadership commitment at the highest, as well as subordinate, levels. While the "top management commitment" mantra has been overused to the point of being a cliche, it nonetheless describes a fundamental reality: *if top management is not deeply committed and personally involved on a sustained basis, then change will not occur.* The OSTF recommends that SecDef Cohen communicate a strong personal determination that the OS Process become the standard way of doing business within DoD, and that he secure the firm and determined leadership of the other principal executives within DoD and the Services.

The prognosis for OS Process implementation is binary, and dependent upon proactive leadership commitment.

Recommendations
- Leadership and Championing -

- **SecDef within 45 days:**
  - Hold off-site with Chairman, Service Secretaries, Chiefs, CAEs
    - Secure personal commitments to Plug & Fight and OS Process
    - Press Conference
      - Shared commitment and Call for Action
      - Announce action leadership
  - Formally request Dongressional, Administration, and industry support
  - DoD-wide call for identification of impediments to implementation
- **Chairman, Service Secretaries, Chiefs, CAEs, Agency Heads within next 30 days:**
  - Take corresponding actions

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Because it is necessary to rapidly implement the OS Process in DoD, several activities are recommended for the near term (45 days).

The OSTF recommends that the SecDef hold an offsite with Chairman JCS, JCS members, Service Secretaries, and Component Acquisition Executives to map out the plan for the change to OS Process. The off-site should stress the necessity of adopting the Plug & Fight/Play and OS Process concepts for DoD systems. The results of the off-site should be announced with significant public exposure at a press conference. The message of the off-site and press conference should be a significant shared commitment and a call for action by all interested parties -- it should announce that the top DoD leadership is firmly committed to the OS Process.

The SecDef should call for identification of all impediments to the OS Process, including inputs from government, the Services, Congress, and industry ... all interested stakeholders. Once the impediments are identified, they should be removed by the most efficient process possible. If an impediment is either due to, or a consequence of, legislation, then Congress should be approached to change the law.

It will be necessary to gain support of all stakeholders for DoD to successfully implement OS Process. Without soliciting the opinions of Congress, Administration, government, the Services, and industry, the chances of success are significantly diminished.

THE UNDER SECRETARY OF DEFENSE

3000 DEFENSE PENTAGON
WASHINGTON, DC 20301-3000

ACQUISITION AND TECHNOLOGY

14 July 1997

MEMORANDUM FOR THE CHAIRMAN, DEFENSE SCIENCE BOARD

SUBJECT: Terms of Reference – Defense Science Board Study Task Force on Open Systems

I request that you establish a Defense Science Board Task Force to examine the benefits of, criteria for, and obstacles to the application of an open systems approach to weapon systems, and to make recommendations on revisions to DoD policy, practice, or investment strategies that are required to obtain maximum benefit from adopting open systems. The Task Force should examine application to new defense programs, to those that have already made substantial investments in a design, and to those that are already fielded, across the spectrum of weapon systems, not just those heavily dependent on advanced computers and electronics.

Within today's national security environment and budget constraints, the Department of Defense has chosen a strategy of relying heavily on the private sector for achieving needed operational performance and cost of ownership for its weapons systems. An "open systems approach" appears to be an effective way to field superior combat capability quicker and at a more affordable cost. Open systems may achieve improved performance and lower costs by taking advantage of competition and innovation in the global, commercial marketplace. In addition, open systems could serve to insure that the US military has access to cutting edge technologies and products, and prevent the Department from being locked into proprietary technology. On the other hand, there will be increased up-front costs for open systems that must be traded against the downstream benefits.

The Task Force should address the following questions:

- What criteria should be used to identify specific programs that would benefit most from an open systems approach?
- How can programs that are already committed to a design (whether in development, production or retrofit) obtain the benefits of an open systems approach? As an example, examine the potential for increased application of open systems for the F-22 program.
- What are the implications of open systems for international cooperative programs? How should the Department quantify the life cycle costs associated with an open systems approach? What other metrics should be used for judging the value of open systems (e.g., reduction of cycle time, fielding of new technology quicker)?
- What tools (e.g., COEA tools, wargaming, costing, risk assessment, related models or simulations) must be developed to facilitate the use of an open systems approach?

- What are the principal barriers to adopting open systems? How can the Department achieve broader acceptance of an open systems approach for weapon systems?
- What level of industry support is needed for adopting an open systems approach and how can the Department encourage such support ? How should the Department select which standards and architectures to use?
- What are the risks and other disadvantages associated with adopting an open systems approach, and how can the Department mitigate those risks? How are weapon systems different from commercial systems? What requirements cannot be met through use of Commercial Items?
- What changes are needed in policy, practice, or investment strategies to implement an effective open systems approach? What investments are needed in the near-term? What means of enforcement are needed?

The Director, Strategic and Tactical Systems will sponsor the Task Force. Mr. Peter Marino and Dr. Wayne O'Hern will serve as the Task Force Co-Chairmen. Mr. H. Leonard Burke will serve as the Executive Secretary, and Maj. Wynne Waldron will serve as the Defense Science Board Secretariat Representative. The Task Force should begin its work as soon as possible and provide a final report within twelve months.

The Task Force will be operated in accordance with the provisions of P.L. 92-463, the "Federal Advisory Committee Act," and DoD Directive 5104.5, the "DoD Federal Advisory Committee Management Program." It is not anticipated that this Task Force will need to go into any "particular matters" within the meaning of Section 208 of Title 18, U.S. Code, nor will it cause any member to be placed in the position of acting as a procurement official.

//signed//
R. Noel Longuemare
Acting Under Secretary of Defense
(acquisition and Technology)

OSTF Membership

Dr. Wayne L. O'Hern, Jr., Chairman	**Technology Strategies & Alliances**
Mr. Jack E. Bloodworth	Boeing Company
Lt Gen Bruce K. Brown, USAF (Ret)	consultant
Ms. Shawn A. Butler	Carnegie Mellon University
Dr. Larry E. Druffel	SCRA
Dr. Vitalij Garber	Garber International
Mr. Jeff Harris	Space Imaging EOSAT
Lt Gen Carl O'Berry, USAF (Ret)	Motorola
Mr. Tofie M. Owen, Jr.	SAIC
Professor Dee Ritchie	Georgia Tech
Mr. James M. Sinnett	Boeing Company/St. Louis
Dr. David E. Sundstrom	Lockheed Martin
Mr. Chris Waln	TASC
Mr. John Wehmeyer	SRI International
Professor Patrick Winston	MIT

DSB TASK FORCE ON OPEN SYSTEMS
APPENDIX C

LIST OF PRESENTATIONS

The following table lists presentations briefed to the DSB Task Force on Open Systems:

Date	Presenter	Organization	Title
Sept. 16, 1997	Mr. David Ream	Director, Standards of Conduct Office	Standards of Conduct
Sept. 16, 1997	RADM John Gauss	N60	Open Systems: An Operational Perspective
Sept. 16, 1997	Dr. Michael Frankel	SRI International	Army Science Advisory Board : Technical Information Architecture
Sept. 16, 1997	Mr. Reginald Varga	Director, Open Systems Avionics, Boeing - Phantom Works	Open Systems Architecture and the aircraft defense industry
Sept. 16, 1997	Mr. William Kiczuk	Raytheon TI Systems	Enabling Open Systems Architectures
Sept. 16, 1997	Dr. Patrick Winston	MIT	NRAC Committee Report on Open Systems: CVX Flexibility
Sept. 17, 1997	Mr. Jack Bloodworth	Boeing Company	Open Systems Architecture
Sept. 17, 1997	Mr. Tofie Owen, Jr.	SAIC	Supportability Perspective on Open Systems
Sept. 17, 1997	Dr. David Sundstrom	Lockheed Martin Tactical Aircraft Systems	Open Systems : A Lockheed Martin Perspective
Sept. 17, 1997	Mr. Leonard Burke	OUSD(A&T) OS-JTF	Open Systems Implementation Progress
Oct. 9, 1997	Mr. Richard McNarmara	NAVSEA/PMS 450	New Attack Submarine Combat System: COTS and Open Systems Initiatives
Oct. 9, 1997	Mr. Tom Graves	ASC/AZ	Performance Based Business Environment
Nov. 18, 1997	Dr. George Heilmeier	Chairman Emeritus, Bellcore	Meeting the Open Systems Challenge
Nov. 18, 1997	VADM Jerry Tuttle (Ret.)	Oracle	Navy Perspective on Open Systems
Nov. 18, 1997	Col Chuck Adams (Ret.)	Coopers & Lybrand	Acquisition Reform Implementation, Industry Survey
Nov. 18, 1997	Col. Diana .L. Beardsley	Director, Avionics Management Directorate, WRAFB	Common Avionics
Dec. 17, 1997	Mr. Dave Kier	Deputy Director National Reconnaissance Office (NRO)	System of Systems
Dec. 17, 1997	Dr. Frank Perry	DISA/D6	Common Operating Environment
Dec. 17, 1997	COL Garrettson	DISC4	Army Open Systems Architecture
Dec. 17, 1997	Mr. Dale Adams	AMC	Modernization through Spares
Jan. 27, 1998	Mr. Al Newman	MITRE Corporation	Joint Tactical Radio System (JTRS)
Jan. 27, 1998	Mr. John Osterholz	Deputy Director, CISA	Joint Technical Architecture
Jan. 27, 1998	Ms. Tricia Oberndorf	Carnegie Mellon University/SEI	Software Engineering Institute
Feb. 23, 1998	BG "Mitch" Mitchell	NRO -Director of Communication	Classified Briefing
Feb. 23, 1998	Mr. Chris Waln	TASC	Task Force Assessment on JTRS
Feb. 24, 1998	Mr. Alvin Burgemeister	Boeing Commercial Airplanes	Air Transport Open Systems: A Mixed Success
Mar. 17, 1998	Mr. Fred Ziska	Rockwell Collins	Advantages of Supplier Configuration Management Control and Open Systems Implantation
Mar. 17, 1998	Mr. Leonard Burke	OUSD(A&T) OS-JTF	Status of Work on Final Report
Apr. 6, 1998	Mr. Peter J. Hancke, et al	Lockheed Martin	NSSN, Using COTS in Military Systems
Apr. 7, 1998	Messrs. T. Burbage, M. Broadwell, D. Mayotte, F. Spring, G. Hogarth	Lockheed Martin	F-22 Program Overview
Apr. 7, 1998	Mr. Jon Ogg	F22 SPO	F-22 Integrated Avionics Architecture
Apr. 7, 1998	Mr. Ken Fehr, et al	ASC/YFFA	F-22 Avionics Lessons Learned

JUSTIFYING OPEN SYSTEMS: WHY DO WE CARE?

by GEN Bruce Brown, USAF (Ret)

"The nature of modern warfare demands that we fight as a joint team. This was important yesterday, it is essential today, and it will be even more imperative tomorrow. Joint Vision 2010 provides an operationally based template for the evolution of the Armed Forces for a challenging and uncertain future."

John M. Shalikashvili
Chairman of the Joint Chiefs of Staff

It is the view of the DSB Task Force on Open Systems (OSTF) that Joint Vision 2010 represents a sound and thoughtful roadmap to the future for the DoD as it works its way through the thicket of uncertainties and alternative futures that face it in the aftermath of the Cold War. While accommodating change is always difficult, the new and uncertain world which results from the fall of the Soviet Union presents the Department with one of the most significant discontinuities with which it has ever been faced. The fallacy of attempting to plan precisely in such an environment is well understood; the danger of being precisely wrong is unacceptably high.

A vision describes a desired end state. The end state that Joint Vision 2010 describes is composed of the aggregate capabilities that our forces must posses to ensure U.S. military superiority, leadership, and the security and prosperity of the American people in the twenty-first century. The opening paragraph of Joint Vision 2010 states:

> "Joint Vision 2010 is the conceptual template for how America's Armed Forces will channel the vitality and innovation of our people and leverage technological opportunities to achieve new levels of effectiveness in warfighting. Focused on achieving dominance across the range of military operations through the application of new operational concepts, this template provides a common direction for our Services in developing their unique capabilities within a joint framework of doctrine and programs as they prepare to meet an uncertain and challenging future."

More specifically, Joint Vision 2010 describes an end state set of capabilities which are <u>radically</u> different from those our forces possess today:

> "Enhanced command and control, and much improved intelligence, along with other applications of new technology, will transform the traditional functions of maneuver, strike, protection and logistics. **These transformations will be so powerful that they become, in effect, new operational concepts."**

Consistent with the template laid down by Joint Vision 2010, each of the Services has published a vision of its own which is focused on its unique capabilities. The Army has published Army Vision 2010, the Navy Forward From the Sea, the Marines Operational Maneuver From the Sea, and the Air Force Global Engagement.

In addition, the Joint Staff has published Concept for Future Joint Operations, which

> "expands Joint Vision 2010's new operational concepts to provide a more detailed foundation for follow-on capabilities assessments... As the implementation of Joint Vision 2010 unfolds and our concepts of joint warfighting evolve, the essential task is to gain the complete commitment of the Services, the combatant commands, and civilian and government agencies to achieving the key characteristic we seek for our Armed Forces—the ability to conduct dominant operations across the full range of possible missions—Full Spectrum Dominance. We have made great strides in developing our joint warfighting capabilities in the last ten years. ***But the challenges of the 21st century demand a new legacy of commitment to joint warfighting.***"

Descriptions of the uncertain future world our forces face and the changes that they must make to prepare for it are not limited to the Joint Staff and the Services. For instance:

- A prevailing theme throughout the Quadrennial Defense Review is the necessity to transform today's forces into a much more joint force required for the future.

- The Defense Reform Initiative characterizes itself as the third element of a DOD corporate vision to transform defense strategy, the military, and the business practices of the Department in order to prepare for the 21^{st} century.

- The National Defense Panel report is titled Transforming Defense; National Security in the 21^{st} Century. The report is entirely concerned with describing the numerous and profound changes that will be needed to ensure U.S. national security in the 21^{st} century.

- In remarks to the Center for Strategic and International Studies on May 22, 1997, Secretary Cohen said:

  > "In March, I went out to Ft. Irwin to see the US Army's Force XXI experiments in which the Army's Experimental Force is harnessing the power of digital technology and using the capability it provides to test out new operational concepts, doctrine, tactics, and organizational designs. It was an awe inspiring demonstration. Few who see it in action can doubt that Force XXI will revolutionize land warfare by linking commanders, planners and shooters with digital information and communications technology, cutting through the fog of war. Force XXI is the much-vaunted 'Revolution in Military Affairs' made real..."

There is a strong and constant theme throughout these documents that the defense budget is not going to increase and that the demand for forces is not going to diminish significantly. It is clear that the Department has expended and is expending significant resources in the process of thinking about the future and attempting to understand what qualities and attributes our forces must possess to maintain military superiority in the 21^{st} century.

It is also clear that there is one fundamental attribute which is critical to the success of future U.S. forces and which underpins all concepts of future force effectiveness. This fundamental attribute is JOINTNESS. **Our forces are going to have to reflect a degree of jointness unprecedented in the history of U.S. armed forces.** In a word, the key to the success of U.S. forces in the new and uncertain world facing them is :

JOINTNESS!
JOINTNESS!
JOINTNESS!

HOW IS JOINTNESS ACHIEVED?

The Task Force has attempted to identify alternative paths to achieve the levels ofjointness which have been described by the leadership of the Department as critical to the success of future U.S. military operations. To achieve these levels of jointness, however, will require much more than a technical solution. Achieving "a degree of jointness unprecedented in the history of U.S. armed forces" will also demand major institutional and organizational changes, including major changes in many familiar Department processes. Many of these processes, such as establishing requirements, force readiness, training, developing and validating doctrine, and many more, have today a heavy Service focus which will have to be broadened to produce a much more intense joint perspective. That, in and of itself, will be a difficult task, which the Task Force will leave to others such as the U.S. Atlantic Command (ACOM) which was established to help facilitate the *joint integration and training* of our forces.. The Task Force will confine itself to recommending those technical changes which it feels will be required to provide the means to implement the necessary institutional and organizational changes throughout the Department.

WHAT DOES JOINTNESS MEAN?

In that context, therefore, and from the perspective of recommending a technical solution, what does "jointness" mean? Purely and simply, it translates into "interoperability". There is a strong consensus within the Task Force that the operating concepts identified in Joint Vision 2010 and in Service and other joint vision statements have little chance of being successfully implemented unless there is a major increase in the level of interoperability displayed by defense systems in joint operations in the future.

Rapid deployment of highly lethal forces over long distances on very short notice is both an implicit and explicit requirement of the several current vision statements. This means that the U.S. must be able to custom build mission-specific forces from widely scattered and functionally disparate "piece parts" on the fly and do it right the first time. It means we can no longer afford the luxury (not that we ever could) of redundant force elements which characteristically result from Service-unique, stovepipe solutions, including the heavy, ponderous concomitant Service-unique support tails required. Instead, each Service must be able to provide what it does best in the form of light, agile force elements capable of being quickly and smoothly integrated into a coherent and lethal whole.

The force of the future must be redesigned to meet the needs of a volatile and ever changing world. It must be composed of mutually supportive forces able to react to a short or no-notice crisis. Uncertainty and a growing complexity make it difficult to prepare for or even predict the types of contingencies our forces may have to face. Future force projection may be executed by a joint force or even a multi-national force. Modern operations will almost certainly be unified in nature, joint, interagency and multinational.

One of the problems with a no-notice crisis and deployment is that the right combination of forces is not always available or even in close proximity to the area of conflict. The responding CINC needs to be able to use the forces at hand (close to the area of conflict) when asked to respond to these "come as you are crises". In the future he will not have the luxury of building up his forces from far flung staging areas. He will have to "plug and fight" with the forces at hand. These forces will have to arrive in-theater ready to fight.

The ability to integrate large, diverse force elements into a complex but manageable and combat effective whole has long been a military discriminator, and, in modern times, no major power has been as good at it as the U.S. But the doing of that generally has taken a long period of time, both from the standpoint of deploying the forces and, once deployed, organizing and preparing for combat. Recent Defense Science Board Task Forces have concluded that future rogue states are likely to have learned that lesson well and will therefore move quickly in any future aggression so as to deprive the U.S. of time we have historically needed to respond. These DSB Task Forces, accordingly, have recommended solutions involving small, distributed forces that will require levels of interoperability and information technology which is truly "unprecedented in the history of U.S. armed forces".

INTEROPERABILITY ACROSS THE ENTERPRISE

It will profit us little, however, if we are able to solve the difficult problem of interoperability only for the combat forces. Light, agile, and lethal combat forces will have little military utility if the elements of the enterprise upon which these forces depend remain large, ponderous, Service-unique, and heavy.

Our forces will primarily be CONUS based and will depend on a combination of airlift and sealift for their rapid mobility. In all likelihood, these limited airlift and sealift resources will be sufficient to move only the combat forces themselves; it is unlikely that these lift forces will be able to transport the typical combat support and combat service support forces of today over the distances and within the timelines we now consider likely. The combat forces, therefore, that will make up these future joint task forces must be able to provide needed tactical, **and logistical**, personnel and medical support to each other across the enterprise. These forces will have to arrive in-theater ready to fight as members of the CINC's joint forces. These operations will require interoperability between the forces of our different services and between forces of different nations not only with respect to combat operations, but with respect to logistic, personnel, and medical support as well.

For the purpose of this report, "logistics" means the entire spectrum of support at all echelons of command. Future logistic, personnel, and medical support systems must provide interoperable, comprehensive, and responsive support to the Joint or Combined Force Commander. The joint logistic, personnel, and medical support forces of the future will have to be able to do such things as:

- Replace common equipment components throughout the joint or combined task force
- Provide equipment maintenance to a different service component unit
- Exchange parts, fuel, and ammunition
- Electronically exchange logistic support data and information rapidly and accurately in order to support our just in time delivery of critical combat equipment and supplies

- Electronically exchange personnel data and information on casualties and personnel loses in order to effect replacement personnel, casualty notification, prompt payment of death gratuities, etc.
- Electronically exchange the medical status of our forces as they wear the personnel body suits of the future
- etc.

Interoperability across the enterprise, then, extends to at least the following four general categories:

- How we create the force (how it is recruited, trained, organized and equipped. It ensures we prepare to fight in a joint manner)
- How we generate the force (projecting the force and mixing the forces. It requires us to work joint procedures, policies, and plans to ensure success.)
- How we sustain the force (our ability to supply, service, sustain and maintain the force.)
- How we structure the force (our ability to organize forces with the a mix of combat, combat support, and combat service support units.)

Many of the necessary changes have already been identified in the Quadrennial Defense Review and the report of the National Defense Panel. The Defense Reform Initiative is a welcome and long-overdue serious and energetic effort to produce substantial improvement in the operation of the Department by streamlining organizations for agility, investing in people, exploiting information technology, and by breaking down barriers between organizations.

However, the attainment of the degree of jointness demanded by Joint Vision 2010 will require substantially greater change throughout the enterprise than apparently is presently contemplated. Major changes will also be required in such fundamental areas as industrial policy, the current acquisition system, to include particularly major changes in program management policy, and similar enterprise-wide activities. To restate the point made earlier: there is no point is solving the interoperability problem for the combat forces unless that solution is extended to the support forces as well. Light, agile, and lethal combat forces are of no value if they are tied to the logistical support forces of today.

JOINT INTEROPERABILITY IS MANDATED

DoD Regulation 4630.8, Information Interoperability (draft) mandates that:

a. All systems shall be considered for JOINT use.

b. Interoperability requirements shall be reflected in the requirements documents and approved by the Joint Staff.

Systems shall be tested and certified for JOINT interoperability prior to production and fielding.

HOW IS INTEROPERABILITY ACHIEVED?

It is generally agreed that interoperability can be realistically achieved by only two approaches: black box translators and the implementation of an Open Systems Process (OS Process).

Black Box Translators. The black box approach has two major problems; effectiveness and cost. Effectiveness is always impacted adversely compared to an integrated solution, and costs are always high. High costs, not directly evident when a system is being developed or acquired, are ultimately experienced when systems are required to be maintained, spared, P3I'ed, and to interoperate. We become dependent upon (and are at the mercy of) the suppliers of the original system who, because of their proprietary position, are the only qualified entities capable of provided the O&M services of obsolete technology at great cost and typically well behind the state-of-technology in the private sector. Furthermore, when systems are required to interoperate, for example in the C3I domain, proprietary "black boxes" have to be developed to allow "proprietary" systems to be "marginally interconnected". As one system is changed, by virtue of its being under the stewardship of an owning PM, the proprietary "black box" must be changed and the other "proprietary" systems must also be changed --- a significant, spiraling cost penalty being incurred that results in little to no added value to the end user.

The Open Systems Process. The general arguments for Open Systems (OS) revolve around reductions in "cost of ownership" through increased competition for acquisition of technology and products and a reduction in the hidden costs associated with industry proprietary technology delivered to DoD under the protecting umbrella of "we are different". For the purposes of this study, however, the OSTF believes strongly that the military capability demands of Joint Vision 2010 dominate this decision space and, in and of themselves, fully justify the need to begin a rapid DoD transition to OS now.

Nevertheless, "cost of ownership" arguments are powerful and persuasive and add great weight to the imperatives of Joint Vision 2010. Today, weapon systems cost too much because their closed designs are based on nonstandard interfaces which are typically supported by only a few suppliers. Having only a few suppliers limits competition which tends to increase costs, and risks obsolescence should those suppliers fail. As a consequence, today DoD faces an affordability crisis in its weapons systems life cycle costs. Weapons systems continue to be developed with their own, often unique and frequently closed, infrastructures, making upgrading or modifying them over their expected lifetime of 20 to 40 years both problematic and expensive.

An OS acquisition process, on the other hand, bases the weapons system's design on Open, commercially supported interface standards with the prospects of a large supplier and customer base. Reduction in cost of ownership results from being able to procure and maintain systems and technology "off-the-shelf" from the private sector. Cost of ownership is also reduced if we purchase our systems in such a manner that similar technology is used in multiple systems and platforms. Not only do we enjoy volume discounts, but we also get technology reuse across the various systems, thereby reducing the cost of acquisition, sparing, and maintenance.

Increased competition, and the resulting decrease in acquisition cost, comes about by virtue of the definition of "Open Systems" – a technology or product supplied by multiple vendors that adhere to a set of stable standards and interface specifications that exist in the public domain. Furthermore, by leveraging "Open" technology, as compared to reinventing a unique version for each and every system we procure, implies that we can invest our resources for DoD-specific aspects of systems being procured. Duplication of technology, subsystems, components, etc. is minimized, while critical DoD resources are focused on needs which cannot be satisfied through Open COTS products and technology. At a DoD corporate level, acquisition resources that are presently used to reinvent and reimplement technologies with and across service systems would be saved.

Summary. Although there are several ways to achieve interoperability, many of them are not affordable. As a practical matter, therefore, the best way to reach this objective is through the OS Process. The OSTF has been briefed on several current programs which are using the OS Process and was very favorably impressed with three which could well serve as models for the Department: the Intelligence and Electronics Warfare Common Sensor (IEWCS), the Joint Tactical Radio System (JTRS) Program and the New Attack Submarine (NSSN) Program.

WHAT ARE SOME OF THE BENEFITS OF AN OS PROCESS IN THE COMMERCIAL WORLD AND WHAT ARE SOME OF THE COMPANIES SEEKING THESE BENEFITS?

In the commercial world, the benefits that justify using an OS Process are very much the same as those that would accrue to the Department: interoperability, reuse, commonality, affordability, as well as, application portability, distributed systems architectures, data sharing, scalability, technology innovation, plus competitive pricing and vendor independence. The Department is not the only organization which is faced with shrinking budgets and changing business environments. Examples, of some of the companies that have elected to use an OS Process are many and varied (universities, automotive retailers, construction, State government, railways, software vendors, environmental vendors plus the US Navy), are shown below:

1. **Ohio Department of Natural Resources** - Implemented a Geographic Information Management Systems (GIMS) based on an OS approach. The system uses a variety of computer platforms and application software, operating over a sophisticated computer network. The implementation of GIMS in an "Open" distributed computing environment was only possible through the wide use of information standards. The "standards" helped facilitate data capture, translation, exchange, and documentation.

2. **UNISYS** Integrated Information Environment OS Process. Unisys describes their experience in moving to an OS Process as follows:

   "To Unisys, Open means combining the hardware and software products from different vendors to form a seamless information network that is aligned with vendor neutral or independent standards. The key to fulfilling information technology requirements in interoperability. Interoperability is the ability to bridge from the hardware and software components of one vendor to the hardware and software components of another vendor. By creating a seamless information infrastructure that delivers information "on demand," interoperability helps an enterprise concentrate on its business processes, decision making, and customer service. Unisys is committed to the idea that an enterprise should be free to focus on implementing its business strategy and not on interconnecting incompatible hardware and software. OS and standards are the key to achieving this goal. They provide an enterprise with the flexibility it needs to build information systems from the technology that best meets it needs, regardless of vendor."

Unisys required a system that permitted its users to exchange information and be able to interpret and act upon that information, regardless of the manufacturer. The architecture of the system should document the industry standards and information technologies the enterprise has already adopted as well as any new or emerging standards and technologies that the enterprise wants to integrate into its existing network. Its OSA identified the need for its users to access and for the enterprise to manage, information that resides on different platforms and at physically remote locations.

3. **ALLDATA Corporation** - The automotive industry has numerous standards to insure that things work together. For example, companies that manufacture wrenches, companies that manufacture bolts and companies that manufacture automobiles all comply with a set of standards for bolt dimensions. The bolt manufacturer complies with a standard that clearly defines the bolt head, length, width, thread and strength requirements. Since these standards are accepted, the wrench company can make a wrench that can be used on the same type of bolt regardless of who the bolt manufacturer is. The automobile manufacturer can use this standard bolt from a wide range of vendors, get competitive pricing and know that their tools can be used on this bolt. In essence, an OS Process allows you the freedom to choose, while still getting the greatest value for your money.

4. **Hermes** - The Hermes community is committed to implementing OS solutions for freight and passenger applications between the Hermes railways. At the heart of this commitment is an affirmative commercial strategy for reducing costs, portability of applications, interoperability of IT products and components within and across enterprises, scalability of systems implementation, and reduction in obsolescence and future proofing. It is in the long term interest of both the Hermes community as a whole and the individual Hermes railways to adopt information technology and communications infrastructure that optimizes operational effectiveness and commercial viability, and to reach outward to provide services to non-railway organizations and connect with new railways. This can be accomplished using an OS solution. It is generally recognized that the adoption of OS solutions is intimately linked to the future of the Hermes community as a whole and that of the individual railways. The concept of OS is founded on interoperability between systems, not between system components.

5. **Trafalgar House Construction** - UK-based Trafalgar House Construction has implemented a multi-million pound OS strategy affecting all areas of its business. With over 150 systems being installed at permanent and temporary office and construction sites in the UK and worldwide, Trafalgar House was looking for an OS strategy. A strategy which offers interoperability, so that computers from different vendors can communicate; scalability, so that systems can grow; portability, so that applications can be transferred to run on different machines; and consistent operation, so that from both a user and systems administration point of view all systems within the company are the same. They used to manage their system with a staff of 60 and now having implemented an OS solution that can manage the network with a staff of 45 even through the network and number of systems has grown.

6. **The Colt Group** - A UK-based company specializing in designing, .manufacturing and installing industrial and commercial environmental control systems. Colt decided to revamp its information systems using an OS Process. Colt identified several key elements of its new policy; to enter and store data only once; to have a single User Interface allowing common access to all applications; to eliminate the use of custom or handmade software; and to facilitate easy inter-site communications. This strategy was based upon developing a Colt system from standard "Open" elements and then deploying an appropriately scaled and configured version at each Colt location.

YES, WE DO CARE!

Of the several capabilities which we must develop to ensure continued U.S. military superiority in the 21st century, two loom particularly large: the vastly improved interoperability which will be required to maintain and improve the combat power of the smaller, lighter, more agile forces of the future, and the much improved affordability of future forces that will make possible their continual modernization within what are likely to be level budgets.

There are some who criticize the Department today for what they consider to be its insatiable desire for glitzy, high tech weapon systems despite the absence of what they consider to be a concomitant threat.

The Task Force stands in strong opposition to that view. WE ARE NOT INTERESTED IN PUTTING OUR CHILDREN OR GRANDCHILDREN INTO A FAIR FIGHT. If the national interests of the United States are to be served in this new and uncertain future, we have a high obligation to them to ensure that they are provided with the best possible weapons systems—weapons systems which will enable them to dominate any future conflict and bring it to a quick and favorable solution with a minimum loss of life. Perhaps the single most important step we must take to make that vision a reality, given our shrinking budget, is by means of an OS solution to interoperability.

DSB TASK FORCE ON OPEN SYSTEMS
APPENDIX E

A PERSPECTIVE ON ISSUES ASSOCIATED WITH IMPLEMENTING OPEN SYSTEMS

by Shawn Butler, Larry Druffel, Jeff Harris, and Patrick Winston

DoD operates in a systems-of-systems environment.

DoD acquires systems that are both composed of multiple components (subsystems) and are themselves part of larger systems. Just as the user operates in the context of a larger organizational context requiring interaction with others, the system also must operate in a larger context and be capable of interoperating with other systems.

In a system acquisition, the objective is to acquire a capability that meets functional (warfighting) requirements. In addition to these functional requirements for warfighting, the system must exhibit non-functional attributes that stem from the context in which it is to operate. Examples of these attributes include the need for interoperability with other components, portability across platforms, and supportability of the system through its lifecycle, with affordability becoming an increasingly important driving factor. These non-functional attributes "ilities" are just as important as the functional requirements and may dominate the decision process.

One way to get a handle on the complex issues raised by the Open Systems (OS) concept is to think in terms of three levels: the warfighting level, the technical level, and the business level.

The functional requirements and essential attributes are defined at the warfighting level. To achieve the warfighting requirements, additional attributes will be introduced at the technical level. Finally, other attributes will be introduced at the business level. Some aspect of an attribute may be imposed at all three levels, for different reasons. It is useful to be clear about the level at which the requirement for an attribute is introduced so that an attribute at a lower level not conflict with an attribute at a higher level. This needs to be an iterative and interactive process, not a strictly hierarchical one.

The context for the system and the attributes it is to exhibit should be defined by, but not necessarily limited to, the operational architecture and should be supported in the system architecture and the technical architecture. To the extent that these are not made explicit, they should be derived and priorities determined, recognizing that attributes may be in conflict that must be resolved as part of the engineering tradeoff analysis.

For systems involving computer hardware and software, DoD is finding that use of commercial products and standards offer an attractive alternative to developing a military unique system. While commercial products seldom precisely meet the full set of functional requirements, they may still be attractive if the user is prepared to adapt the requirements to commercial offerings. For more complex systems, integration of several commercial products often provides a very attractive option for achieving the attributes. Indeed the commercial world has refined this approach into an "OS" strategy for more easily integrating components into a system to achieve the non-functional attributes, particularly affordability.

OS is not the objective. The objective is to acquire and sustain a capability that is defined by warfighting requirements and that exhibits certain attributes that support the derived technical and business considerations. When combined with other commercially motivated strategies, OS is a means to achieving an implementation of a needed capability. In the ideal, it provides a strategy for assembling components into a system (and systems into a system of systems), often described as plug and play.

Characteristics of OS and their contribution to achieving non-functional attributes ("ilities").

While there are a variety of definitions of OS that often lead to non-productive debate, it is more useful to consider the characteristics of OS and consider how these characteristics affect our ability to achieve the non-functional attributes.

Interoperability: We are interested in whether components can interact as well as the costs or efforts to get them to interact. The definition of interoperability (The capability for two or more components to interact) overlooks the questions of cost and effort. In light of this, we define interoperability as the potential for two or more components to share information.

The interoperability system attribute can be both a functional and non-functional requirement. It is a functional requirement because requirement documents often specify that certain components must interoperate. It is a non-functional attribute because in general we want systems that can interoperate with other unspecified systems. Although interoperability is difficult to test, the use of standards, COTS and modular design reduces the amount of effort needed to achieve interoperability.

Portability: The potential for a system to operate on different platforms. Portability is achieved through design and standards. Standards are used to minimize the differences among different platforms. When standards can't support the implementation then the system design must minimize the system's reliance on proprietary interfaces and extensions. Portability is a non-functional requirement because we cannot always anticipate the platforms on which components will operate. For example, when Joint Maritime Command Information System (JMCIS) was built, the program manager never anticipated that JMCIS components would run on the variety of platforms that they do today. However, if the program manager had specified that JMCIS must be portable enough to run on three top selling hardware platforms, he would have been thought crazy. A measure of system portability is the level of effort required for a system to work on multiple platforms. The penalty of maintaining system portability is that it can increase system supportability costs.

Scalability: We define scalability as the potential for a system to grow and accommodate more and more users, or additional functionality. As systems are interconnected and more and more information is shared among different levels of operations, it is essential that the systems built today can handle the additional stress of these interactions. As expectations change about what our current systems capabilities should be, a scalable system can absorb the growth.

Supportability: Supportability can be defined as "the actions related to the reliability, maintainability, and affordability of component implementations, and the integrated logistics support and configuration management required." [1]Reliability can be tested and is usually a functional requirement. Maintainability and affordability are difficult to test, but highly desirable system properties. Maintainability is a function of software design such as modularity and abstraction, and good software engineering practices such as described in the Capability Maturity Model or ISO 9000. Using standards and COTS products leverages affordability. COTS products reduce the need for customized development. This reduced need allows amortized cost of new functionality across a greater customer base.

Performance: Performance is the capability of a system to meet requirements. Performance is a system attribute that is normally specified in requirement documents, however, it is unique because requirements may be met at the cost of supportability, portability, or another system property. For example, real time system requirements may dictate customized software. Customized software decreases system supportability.

These are only some of the characteristics of Openness. One can see from this small subset that some of these attributes conflict. The program manager's job is to find the appropriate balance among the characteristics, knowing that as performance requirements increase, the system could become less open.

One reason to achieve Openness is to reduce the cost of making changes to the systems when unanticipated requirements dictate. A common thread throughout each of the descriptions is that the degree to which a characteristic contributes to the Openness of a system depends not only on its contribution when building the system but equally on its contribution to the ease with which a system can be modified or maintained. Scalability is not a requirement unless the system must grow. Portability is not a requirement unless the system must work across multiple platforms. These Openness characteristics become important at various stages in the software development cycle. Scalability and portability are desirable because there is empirical evidence to show that systems do need to be scalable and portable, and the cost to achieving these attributes increases as the system matures.

This means that the program manger must balance all system stakeholder requirements. Stakeholders are the warfighters, acquisition specialists, maintainers, and vendors. Each stakeholder places different and sometimes competing demands on the program manager. The program manager's job is to maximize system capability within the resources allocated. The program manager does this by leveraging OS characteristics. These characteristics are essential to a system if the program manager is trying to maximize the requirements with the system functionality. These "ilities" are the key to leveraging warfighter functionality.

Standards and software design achieve almost all of the OS attributes. Standards have received the most emphasis because they are concrete and testable. Design characteristics are more subjective because it is difficult to quantify why one design is more scalable than another, or why one design is more supportable than another. There a small metrics that give software engineers insight about the characteristics, but evaluation of software designs are usually left to experienced software architects and engineers. In general, the more robust and flexible a design the more Open the system. Similarly, as standards are selected based on their commercial support and

[1] Open Systems: The Promises and the Pitfalls, Meyers and Oberndorf, Carnegie Mellon University, 1997.

public acceptance, the more Open. Although software design is difficult to evaluate with respect to OS, it is as significant as standards in its contribution to OS.

System design and implementation should be guided by an architecture defined and managed at the level that has authority over all the systems affected.

To achieve the attributes ("ilities"), the operational, systems, and technical architectures must be defined. The technical architecture must bind those elements which are essential to achieving the desired attributes and leave unbound those elements that are not essential to achieving the desired attributes. While this is easy to say, it is difficult to define. It requires considerable judgement based on knowledge of the domains to be covered. These decisions guide the way in which the systems are to be made Open.

Definition and control of the architecture must be vested at that level which has authority over all the systems affected by the architecture. This principle has lead to the suggestion that the architecture can be defined as a top down strategy with refinements at each level. It has been suggested that a natural conclusion of this strategy is that the architecture of the higher level system would stop at the skin of the platform. While this is desirable and appropriate for some elements of the architecture, the complexity of interaction among the various attributes makes it impractical. The following two examples illustrate this point.

The first example stems from the realization that while a platform has an essential warfighting function, it may also be host to some other warfighting function that is incidental to its main purpose but which is important to the context in which it is to operate. The intelligence function is a good case. Various platforms that will engage in a specific operation carry a variety of sensors that may collect information for its primary purpose. That same information may be valuable from an intelligence perspective. While the principal function of the platform may constrain the use of the information at specific times such as the requirement to remain passive to support stealth, at other times the information may be safely transmitted without affecting the primary purpose. That component of the system supporting intelligence should conform to the architecture defined and controlled by the intelligence function.

A second example involves the case of supportability. To increase the supportability of a family of systems, the form, fit and function might be dictatedby a higher level authority to ensure ease of replacement or interchangibility. Alternatively, a higher authority may decide that all systems under its purview will use a specific database system that supports access for real time systems.

These are only examples. There are undoubtedly other instances in which the system in which the new system is to operate will constrain the architectural decisions. This is certainly not popular with program managers who would prefer the autonomy that their predecessors enjoyed in the days when we built stovepipe systems. However, it is the nature of the engineering process in which constraints are placed on design. It is important, therefore, that these higher level architectures bind only that which needs to be bound to achieve the purpose and not overconstrain the design space.

It is tempting to recommend that the architectural controls be defined and managed at the highest level, which would then make the entire defense system one enormous system-of-systems. Implementing such a recommendation would be impractical for technical and cultural reasons. At the technical level, the diversity of systems and the complexity of the various attributes makes the technical feasibility questionable. Secondly, there are simply too many variables to expect individuals to accommodate the level of complexity that would be introduced. Finally, it would require a fundamental shift in the overall organization that is probably not warranted.

There is, however, a practical level at which this strategy can be implemented within the current structure. The PEO structure generally covers the domains over which operational, systems and technical architectures would be both tractable and logical. Therefore, we recommend that the PEOs be treated as product line managers. They should be provided the funding and authority to define and manage the systems architecture and technical architecture over their systems. They are in a position to work with their warfighting customers to develop the operational architecture and to make the decisions necessary to trade the attributes against the specific system performance and functional capabilities.

While practical, this recommendation is not ideal. First, the PEOs are aligned along Service lines. Therefore, architectures for those domains, such as the aircraft and avionics architectures which could be common to the three services, will not necessarily be consistent. Likewise,PEOs -- making valid technical and business decisions with their respective program managers -- will undoubtedly choose standards and products that are inconsistent with those of other systems over which commonality might be important. In some cases, such as C^4I, there is existing structure and progress toward a joint technical architecture. Similar joint efforts might be mounted for other domains.

One idea presented to the OSTF that should be considered is to develop a resource to maintain visibility into the choices of standards and products being made for each of the technical architectures. Supported by a rich database, this function could identify when technical architectures are choosing incompatible standards and also maintain a community of interest in specific standards and products. This should be a monitoring and alerting function and a resource to the PEOs. It should not have authority to control.

OS is not a binary decision that is implemented uniformly throughout a system. It must be based on a clear vision of the objective capabilities needed.

Through the process of systems design, various components are defined. For each component and its interface, a variety of design decisions must be made. Among those decisions should be the degree to which that component will be made Open. While the decision process should be guided by a consistent set of principles, different components of an "Open" system may be closed. This section will consider some of the decision criteria that might be used to guide that process.

The context for the design decision process is set by the overall architecture (operational architecture, the systems architecture and the technical architecture). These three architectural views traditionally have not been made explicit within DoD. There are efforts underway to address them within the C4ISR community. The greatest progress seems to be with the Joint Technical Architecture. While this is an important start, a technical architecture without an operational and systems architecture provides too little guidance to the design process.

Ideally, there would be a hierarchy of architectural descriptions with a responsible chief architect at each level. The chief architect at each level would provide guidance to subordinate levels that would guide the design decisions including the extent to which a specific component needs to be

Open. Absent that guidance, the chief architect for the system must make his/her own best guess based on an understanding of the non-functional attributes. When a systems architect is not provided an architectural context in which to operate, he/she must be particularly sensitive to these questions. While the system may not need Openness, other systems in the context it shares may demand it.

As each component is defined, whether that component is to be implemented in hardware or software, the architect should consider the following questions.

Can the required functionality (or some major component of it) be realized by using a commercial product or standard? In an ideal world, system decomposition would follow a top-down process driven solely by the system requirements. However, in today's computer systems environment, a bottom-up driven process of assembling existing components has higher leverage than ab initio development. Therefore, the first practical question should be whether an existing product meets a sufficient portion of the system requirements to be considered and whether an existing standard will support the requirements. This question must be addressed in an overall architectural context.

The benefits that may be achieved by incorporating existing products and standards are so powerful that it warrants consideration of modifying the requirements to fit an available product. While this has not been accepted practice in the DoD, user stated requirements have varying priorities. The opportunity to use an existing product or standard should not be rejected until the importance of unsupported requirements is given careful consideration and the user makes the priorities clear and understands when a requirement is a driving the decision to be closed.

Is the information generated by this module important to any other element in the larger system of systems context (or likely to be so in the future)? If so, then the information needs to be communicated and the means of communication decided. If the information is needed or might conceivably be needed in the future, then the component is a candidate to be Open.

This question of possible future need deserves more consideration at this time in DoD. At this stage of our system-of-systems development, we are faced with a legacy of stovepiped systems. For a variety of reasons, current Service doctrine would not accommodate making information available to other systems. But evolving visions such as Joint Vision 2010 require that doctrine be reconsidered. DoD system architects certainly do not want to define systems that would make it technically difficult to respond to changing doctrine. Therefore, a component that might otherwise not need to be Open might very well be made Open simply to accommodate a future system-of-systems capability.

Is this component likely to be replaced in the future? Reasons for possibly replacing a unit in the future might include an assessment that:

- The underlying technology is changing – for example, a chipset might eventually replace a group of chips;
- A commercial product that would meet the need is maturing and would be available in the future;
- The functional capability being supported could change – for instance, a component that processes data from a specific sensor would change if the sensor is changed or replaced;

- The component is susceptible to replacement during repair.

Is there an opportunity for developing common modules for similar systems? This question should be asked even for systems that are military unique where the DoD must pay the entire cost, including duplicate investments by related programs. The DoD has already demonstrated significant cost savings and reduced time to market following this strategy. The Army IEWCS and Air Force PRISM programs are two examples.

While there are a number of reasons why a component should be Open, not every component in an OS needs to be Open. When the decomposition reaches a point where the details of the implementation are no longer of concern to the architect at any higher level, and answers to the previous questions are negative, then a closed solution should be acceptable. If functionality is unique to the system or so unique to the military that no commercial product is likely to become available, a closed component may be the most expeditious. Likewise for some essential components such as real time control systems, performance considerations may dominate all other considerations, including Openness. In summary, an OS may have completely closed components or components that are less Open due to a proprietary implementation.

How do we select standards to achieve the benefits of OS.

OS goals are achieved through a process of technical and system architecture development. Part of that process is to select the standards that are appropriate for the system. The system architecture is the context for selecting the standards. Software engineers select standards on the basis of their applicability, maturity, and degree of adoption by the development community at large. The Joint Technical Architecture provides a list of standards that meet the last two criteria; however, system engineers must select the applicable standards. Standards selection is easy if existing systems dictate the interfaces or if the standard is an obvious choice because not selecting it is counterproductive.

Imagine the implications of not selecting Microsoft Windows or NT for the PC. There are other products available for the PC, but most products depend on the Microsoft environment. A choice other than Windows/NT would limit the selection of other COTS products thereby increasing development costs. Experienced developers would be scarce; increased development would be costly. Legacy application integration would be extremely expensive, if not impossible. Following such a decision, administrators would need specialized training once the system is fielded. Follow-on maintenance costs would be at a premium since developers could command a very high price. Although this example may be extreme it illustrates some of the costs of not following the "building codes."

The difficulty in selecting standards arises when the choices are not obvious. Four conditions can make decision making difficult: (1) when a standard has not matured, (2) when proprietary extensions are necessary for performance requirements, (3) when multiple standards exist for the same component, or (4) when a standard does not exist.

A standard has not matured. A specification exists, but either products have not been created or, if the product has been created, the product has not been tested in an adequate number of contexts. An example of this situation is the Common Object Request Broker Architecture (CORBA). The specification preceded an implementation. As products became available and the specification was tested, it quickly became obvious that CORBA was well suited for some applications, but not appropriate for all applications. Within the DoD there was considerable pressure to select CORBA as the middleware for software systems. Since CORBA is not appropriate for all applications, settling on CORBA as the standard for all applications would have been premature.

Proprietary extensions are needed. The specifications may be complete, but do not support system performance requirements. SQL is a perfect example of this condition. There are few developers that adhere to a strict implementation of SQL because they cannot get the database performance necessary to meet the system performance requirements. Developers frequently depend on proprietary extensions that cause a tighter coupling to the database vendor than a more OS approach would dictate.

Multiple standards exist. Multiple standards can meet requirements, but an engineering analysis must be done to select the most appropriate product. However, the decision can result in losses such as flexibility, scalability, or can result in increased costs down the road. CORBA and DCE support distributed computing and both are acceptable choices within the JTA, however, both support different software architectures. Selecting the standard before the software architecture is developed forces the architecture to be consistent with the product, instead of selecting the architecture because it is the best fit for the problem. This is also an example demonstrating that standards are not a substitute for software engineering.

A standard does not exist. System design may call for a specific architecture or software component that does not have an existing standard. This can occur because the product is militarily unique, or no standard exists in the marketplace. Messaging and queuing products do not adhere to a standard.

No decision is black and white. Decision makers must consider the desired "ilities" for the system. Decisions must be made considering the context of the desired system properties.

Systems evolution following an OS strategy requires a different mindset and different approaches than the traditional DoD Systems acquisition.

When a system is developed following an OS strategy, a number of issues must be handled differently than for traditional development. Among the issues to be considered are the following.

Program Management - The Program Manager in the OS development process has a number of competing interests that need to be balanced. The Program Manager needs to be given enough flexibility to make parametric trade-offs on what are seemingly incompatible criteria. A strong motivated and empowered systems architect is mandatory. This person must have knowledge of both the end-user system needs and knowledge of commercial practices, trends and importantly limitations. In DoD the system acquisition specialist must be an informed and educated buyer. This person needs to establish the framework for trades so architecture and development decisions can be responsibly made using the following criteria:

- performance
- required existing and future functionality
- schedule
- flexibility and ease of evolution

- vendor(s) commitment to commercial development
- multiple vs single vendor product availability
- training and operation
- ease of evolution
- initial and life cycle costs
- complexity of middleware software
- database design
- required interoperability

Requirements - DoD must continue the evolution to user statements of need. System requirements must focus on the what and limit the specific specification of the how. Confusion about this will unnecessarily limit the flexibility of the systems designers to conduct trades that favor a more OS approach. Where appropriate, the systems architect should be allowed to look for the knee in the performance curve and recommend the 80% solution. Significant life-cycle resources can be saved if the 80% solution is judged to be compliant with the requirement.

Development Process - The Program Manager and systems architect must recognize that better is the enemy of good enough. One of the powerful advantages of OS is it's ability to incorporate evolving, changing, and sometimes conflicting standards and products. It is an advantage because when chosen properly, the standards are fueled by commercially driven development that will enhance features, connectivity and interoperability.

Program Managers need to recognize this and leave the relative safety of custom development and move to the building block approach of OS. The building block approach is manageable but it must be within a top-level hardware and software system architecture with well documented interfaces. Middleware and graphical user interfaces can provide transparent complexity to the user and support mediated access between system elements. Caution must be exerted that the DoD fit-in and not drive the standards including the desire to always be cutting edge. Recognize that when properly implemented the OS approach provides the opportunity achieve system improvements through evolution as the building blocks of the system evolve.

Recognize early that some DoD needs will not be met with commercial items. Design a process that recognizes this early and does not over anticipate the capabilities of commercial Open solutions. For example, security, recoverability, special environments and hard real-time can be drivers beyond the scope of many commercial solutions. Do not fall trap to the promise of adaptability of a commercial stem to a function it was never designed to do and the marketplace will not support its long-term support.

Configuration Management - The Program Manager is held to cost, schedule and performance. The custom solution is a powerful siren's call given these pressures because the Program Manager will sense improved control. To the contrary, when selected properly the OS elements allow the Program Manager to get started with tremendous functionality at a fraction of the cost. Once selections are made, a *controlled* process for development and operation must be implemented. The systems architect's job is not done.

A configuration management process must be implemented to evaluate the impact of changes that will be continually thrown at the program. For example, the promotion process of new versions of software products will require structured testing to validate interfaces to middleware before the change is fielded. A structured discrepancy review process that allocates resources, assigns resources, evaluates fixes and maintains configuration of the overall process is required. This process must maintain a dialog with the vendors so that changes can be better anticipated and the vendors can receive important feedback from the customers of their systems.

When employing the OS approach, the program manager must be prepared to keep individual components up to date with version changes. This must be a planned process that recognizes two important three important factors. There will be continuing costs that must be budgeted. New versions of commercial products may not always be upward compatible. Two different products that depend on the same underlying third product may assume different versions of that third product.

An OS strategy requires a complementary strategy for migrating legacy systems to become more Open.

Legacy systems are a special challenge. A continual review of the state-of-the-art must be accomplished so the migration of systems can be managed effectively. The resource managers within DoD need to recognize that holding on to the past can significantly increase costs and lower performance. An OS strategy requires a complementary strategy for migrating legacy systems to become more Open.

The decision whether to migrate a system to an OS really depends on the cost effectiveness of the migration. The first step in the decision-making process is identification of OS properties. The program manager must decide what "ilities" are needed. Following this, the program manager must identify the best method for achieving these "itities." This type of analysis can prevent implementation of unnecessary changes. Since the program manager may not fully grasp the overall system's complexities, another staff person with oversight ability must review the initial analysis. The analysis may show that system migration is not cost effective. Such conclusions could lead to a decision to wait and replace the system at a later time.

Several strategies can apply to migrating systems. Although some strategies can be identified, not all can be enumerated because each situation may be different. Changing the entire system to adhere to standards that don't result in a direct benefit to those "ilities" is not cost-effective. The key question is how to anticipate system requirements. There is no easy answer to this question. It is much easier to employ these principles when starting from scratch, as opposed to importing these principles into existing systems.

Trade-offs often accompany each strategy employed to migrate systems. For example, wrapping the system allows encapsulation, but does not increase supportability or modularity. Wrapping the system may increase interoperability. A different strategy such as breaking the system apart and wrapping individual components can increase modularity and component reuse. However, if component reuse is not a goal, the first strategy may be sufficient and would cost less.

In summary, decision making regarding migrating systems must be guided by system requirements and engineering principles.

SUPPORTABILITY

by Tofie M. Owen, Jr.

INTRODUCTION

Our DSB Task Force on Open Systems (OSTF) explored the issue of supportability in terms of the relationship between Open Systems (OS) and the vision of focused logistics as expressed in Joint Vision 2010 and supporting Service documents. As we examined the impact of OS on supportability, we found a number of government agencies and contractors who touched on various benefits on Open Systems Architecture (OSA) and elements related to OSA such as COTS, commercial parts, and commonality. What we found was enthusiasm for OS and commercial products. What we didn't find was a well-structured set of guiding principles and some supporting facts about the impact of OS on achieving the goals of focused logistics.

This section of the Report is organized around the fundamentals of focused logistics, the relationship of these fundamentals to OS, the identification of issues in this area and, finally, a set of recommendations as they apply to both legacy systems and new systems.

TENETS OF FOCUSED LOGISTICS

The four tenets of focused logistics are expressed in JV 2010 are:

1. Reduction in logistics footprint
2. Achievement of interoperability
3. Maintaining the operational edge
4. Lower cost of ownership

REDUCTION IN LOGISTICS FOOTPRINT

As the demand for rapid deployment increases, and the continued need to support the mobile, expeditionary forces as envisioned in JV 2010, more emphasis will have to be placed on reducing the logistics footprint and supporting fighting units on arrival. We considered the impacts of OSA on all aspects of logistics to include: parts, test equipment, tech orders, as well as the maintenance teams.

The key to gaining the optimum benefit from OS lies not only in the implementation of an OSA but to the degree to which the OSAs are standardized and commonality.is achieved across multiple but similar type systems. An OSA based development of a weapon system/support system will enable the deployment of a system that could:

- Have commonality of hardware, firmware and software thereby reducing the number and type of spares to be supported.

- Result in substantial size and power consumption reductions due to multi-function apertures, higher levels of component integration, and consolidation of multiple component cards to a single card. This allows more function or component capabilities per chassis.
- By implementing the principles of OSA in the IEWCS coupled with commonality and the implementation of OSA across six different types of EW systems (both ground and air), army operational units:
  - Required 46% fewer operators, 65% fewer vehicles and 60% less airlift and capacity.
  - Could share testing, operator training, and overall supportability functions due commonality and less operational specialization.
  - Would be able to share personnel and facilities because of the commonality of maintenance tasks and skills required to support IEWCS subsystems.
  - This is clearly a classic case of what is envisioned as emphasis is placed on or reducing the tooth-to-tail support and ultimately the overall logistics footprint.

ACHIEVEMENT OF INTEROPERABILITY AND INTERCHANGEABILITY

The basic premise of interoperability as it pertains to focused logistics is the ability to share assets in order to meet supportability requirements while at the same time meeting and surpassing the operational effectiveness needs. Again, the implementation of an OSA across multiple types of the Army's EW systems resulted in:

- Subsystem and component interchangeability across the Army's individual units and platforms.
- Ease of cross training and flexibility of personnel assignment due to the use of similar display terminals and display formats.
- Use of common databases thus enabling operators to achieve sensor-to-sensor cross cueing.
- Increased joint and international theater interoperability through the incorporation of a similar OSA into other services such as the USMC Mobile Electronic Warfare Support System.

MAINTAINING THE OPERATIONAL EDGE

To maintain the operational edge, we must field and support systems which:

- Provide technological superiority
- Quickly adaptable to meet unexpected/unplanned threats

The OSA-based development of IEWCS resulted in a highly evolvable and fully supported system, which permitted easily upgradeable subsystems and components to meet evolving threats through technology insertion. For example, this provided the ability to incorporate more powerful processors to accommodate more computationally intensive algorithms. Additionally, the implementation of OSA-based system/subsystem permitted easy reconfiguration of each of the major subsystems to meet special mission needs.

In addition to having an OSA-based system, the emphasis on currently available off-the-shelf technology that is soon to be available provides an added benefit. This focus permitted the IEWCS Program Office to develop a system which makes possible a technologically and operationally robust system while maintaining the flexibility to address future electronic battlefield requirements in a timely manner.

LOWER COSTS OF OWNERSHIP

In addition to the overall operational and supportability benefit resulting from the use of an OSA-based system, there are clear indications that there are significant cost savings or cost avoidance benefits.

For example, the use of an OSA-based system across multiple platforms (both ground and air) for the IEWCS resulted in overall total Army cost avoidance of $1B. Of that, approximately 55% of those savings occurred in the R&D and production phase. The use of an OSA-based system coupled with maximum commonality resulted in a reduction of cycle time for the engineering and manufacturing development phase of 18-39% depending upon the particular platform.

Generally speaking, there is already existing analysis to support the premise that overall Operations and Support (O&S) costs can be reduced through the use of an OSA. For example, in the case of the IEWCS program, O&S costs avoidance over a 20-year period is expected to be $436M. This does not include the corresponding cost reductions due to the elimination of unique training vehicles and maintenance facilities associated with having six different legacy systems.

Similar cost savings have been derived from other platforms that have considered the implementation of OS. In 96 dollars, the Air Force believes that it reduced its O&S costs on the F-15E by $140M and correspondingly, the Navy has estimated cost avoidance savings of $117M on the AV-8.

As is generally recognized, software development and follow-on support has clearly become a major cost factor on any weapon system. One way to counter this exponential cost growth is by taking advantage of software reuse. In the Army's IEWCS program, almost 67% of the software was reusable across the six different platforms. But even more telling is the prediction that future updates of the IEWCS could be accomplished with figures approaching 100% reuse. Not only does this reduce overall costs and schedule, but it also reduces risks and provides for a more common baseline for future updates.

In another instance, Northrop Grumman used commercial equipment in an Open standard environment for radar systems being developed for Unmanned Aerial Vehicles. They were able to achieve an 80% reuse in software development between platforms and essentially a 100% reuse of the signal procession software module.

Full implementation of DII COE, extended to include real time applications, could be the vehicle to drive widespread software reuse.

While COTS and OSA are not the same, it is clear that in many cases an OSA serves as an enabler for the use of COTS. This obviously leads to other savings because of the ability to:

- Enhance competition
- Leverage technology
- Achieve economic ordering quantities

This has an effect not only in the apparent reduction of O&S costs but also in R&D and production costs as well.

OTHER SUPPORTABILITY ISSUES

As discussed above, the implementation of OSAs can be a major enabler toward meeting JV 2010 for Focused Logistics. There are four other factors of the supportability issue, which warrant further discussion as they apply to the impact of OSAs and commercial technology. These are:

- Parts obsolescence
- Modification updates
- Maintenance concepts
- Logistics process to include the support of logistics IT systems

Parts obsolescence has clearly become a major problem affecting operational systems today. This impact is felt not only in the legacy systems, but in weapons systems whose IOC is within a couple of years. This problem has been brought on by:

- Aging weapon system problems due to longer than planned operational life
- Past and existing acquisition policies and procedures
- Diminishing manufacturing sources

The scope of the problem applies to the analog/RF market, as well as the digital market. Although solutions may be more evident in the digital market than in the analog/RF market, industry believes that there are potential solutions on the horizon. One example is to evaluate the cellular phone market and similar industries for solutions.

The implementation of an OSA by itself will not solve the parts obsolescence problem. It does serve as an enabler, as previously mentioned, for COTS/commercial parts. Secondly, tied to OSA is the concept of Form, Fit, Function and Interface (F^3I). There is a real opportunity to work toward solving this problem through the:

- Potential for multiple vendors
- Ease of replacement
- Ability to keep up with technology change occurring in the commercial world

One note is that the benefits achieved are generally most attributed and defined for the electronic parts market. For other areas such as mechanical or hydraulics, more work may be required.

The Joint Aeronautical Commanders Group has taken a major step forward in addressing electronic parts availability and diminishing manufacturing sources with their Performance Based Business Environment (PBBE) concepts, but there clearly has to be a cultural change in both DoD and industry in order to be successful. It appears that industry is already moving in that direction, if for no other reason than: "it makes good business sense."

Clearly one aspect of supportability are the benefits achieved through commonality of modifications and updates. The Army's IEWCS represents a classic case of the implementation of OSA across multiple types of systems. Furthermore, not only is there both a reduction in total life cycle costs and reduced schedule, but OSA readily permits technology to be inserted at a later date.

While not necessarily the only factor, clearly the commercial market will influence the maintenance concept. There is already underway a change as shown below:

- 3 levels - Historically
- 2 levels - Currently
- 1 level - Tomorrow

In the non-weapon systems market, such as the medical area, DoD has already moved ahead with the Prime Vendor/Virtual Vendor program concepts. One aspect of these new concepts is the supply chain, insofar as you go directly from initial supplier to user. This eliminates many of the middleman suppliers and distribution organizations.

Another factor driven heavily by the technology explosion, particularly in the commercial market, is:

Mean-Time-To-Obsolescence (MTTO) < Mean-Time-To-Failure (MTTF)

Digital technology is changing at a fast rate. At the same time, parts are becoming more reliable. The DoD appears on the surface to be more influenced by the digital market than the analog/RF market, but the reality is that the problem is the same for both but with some differences in the degree of impact. The problem is not limited to legacy systems: we are already seeing parts availability problems appearing in the F-22, our newest fighter.

The implementation of OSA, while helping to promote a broader source of parts, is not in itself a cure-all. Parts replacements/updates are a problem for the services to solve because DoD has historically budgeted/procured/modified based upon system/parts failure, not upon the need to ensure an adequate source of parts. When availability becomes an issue in programs, DoD has resorted to the classic source of utilizing lifetime buys: clearly not the most cost effective approach, especially in periods of austere budgets.

Thus supportability has to be considered in a new light. In the past, the problem was that parts failed and DoD had to be concerned with availability and the impact that obsolescence and diminishing sources had on the supply chain. Today the problem is reversed and obsolescence becomes a driver rather than a factor when an item fails. Essentially, what this means is that DoD very well may be forced to budget and adapt its supportability concepts to address technology refresh/insertion rather than a parts failure. In this environment, the traditional emphasis on configuration control to support build to print will be replaced by F^3I.

Finally, there is the issue of logistics processes and the supporting IT systems. For the past several years, there has been a clear emphasis on the use of COTS and commercial parts for defense related systems. Most recently, there has been an emergence of interest in the application of commercial logistics processes and commercial IT systems to support the logistics process. The emergence has been accelerated by the demand to:

- Reduce infrastructure
- Improve response times
- Eliminate the large number of logistic IT systems which tend to be both stove-piped and redundant.

Yet at the same time, there is no single organization charted to solve the problems. The Joint Logistics System Center (JLSC) was originally charted to do this, but JLSC is no longer in that role.

Unfortunately, time constraints and the lack of any earlier detailed analysis/studies did not permit us to examine the implications and relationship if any between the use of OSA and these processes and IT systems. However, preliminary analysis indicates that visibility becomes even more important because of:

- Greater number of parts available for substitution.
- Experience (or lack of) of suppliers with regard to levels of support required for their product.
- Inexperience of government in understanding and incorporating commercial warranties and associated terms and conditions.
- Implication of integrating commercial products into existing or planned logistic processes.
- Need to provide adequate documentation to ensure interoperability among prime and sub-contractor systems, as well as across multiple weapon systems which employ the same OSA or share in common modules/parts, as well as common software/firmware

IMPLEMENTATION

There are a number of factors that will dictate the level of implementation of OSA. They are:

A. Overall objectives of the program

B. Technical, costs, and risk impact

C. Physical limitations

D. Type of system

E. System maturity, i.e. where it is in the acquisition cycle

In any case, the decision to implement OSA, particularly on legacy systems, must be supported by a sound business case. For new systems still in the conceptual stage, the application of an OSA at the highest level may be the more prudent choice.

To accomplish this, the program manager/program executive officer must have total performance responsibility for the system/sub-system over its life cycle. This was clearly a dominant factor in the IEWCS since the Army's PEO for IEW had total responsibility for all of the systems involved and for R&D, production, and follow-on support.

In contrast, the Joint Tactical Radio (JTR) program as currently conceived does not offer a program with the same level of management responsibility and authority. While the JTR program office will be responsible for the R&D and establishment of standards and protocols, each service will be responsible for their own acquisition and logistics concepts. This raises a number of questions about the "jointness" and, more specifically, about the ability to save dollars in the supportability area.

The commercial world can certainly affect the decision process with regard to the level of OSA that will be or should be implemented. Generally speaking, the influence of the commercial market on OSA decreases as you go from the board/component level to the weapon system level. The final decision on what level of OSA to pursue, whether for a new system or a legacy system, will depend upon the factors previously discussed above.

The commercial market will continue to have a profound effort upon supportability. This effort will be driven by a number of factors to include:

A. Exponential explosion in technology

B. Expanded market beyond the IT domain to include cellular phones and personal communication devices

C. Increasing reliance on commercial vendors including a broader base to access

Our study found that industry believes that it takes considerably more resources to develop custom designs for embedded systems/sub-systems as typically found in most weapon platforms and for the C^3 applications normally associated with support systems. Most companies that we interviewed felt that the extra effort required to use commercial systems/products or through some level of implementation of an OSA was relatively small compared to costs associated with unique solutions or design of specific products. As one major defense contractors pointed out:

> "However good commercial standards are today, we also need to be cognizant of the additional effort to develop, test and maintain fielded systems using commercial standards over the product life cycle. This is where OS standards will play an important role – to define process standards, as well as the physical ones which maintain OS performance, but in such a way that contractors can interchange their products at a lower life cycle cost to the government."

CONTRACTOR LOGISTICS SUPPORT

While there seems to be a general consensus that the implementation of an OSA can improve supportability, there are two other factors that must be considered.

The first is the impetus of DoD to move to full Contractor Logistics Support (CLS). In this case, the decision of what/how/if to implement an OSA on weapons system will largely be driven by the prime contractor who will/should assume full responsibility for CLS as part of their overall contract.

The issue is how do you, or whether in fact you should, enforce OSAs on programs utilizing CLS. This is compounded by the fact that, more and more, DoD is promoting the concept of Total System Performance Responsibility (TSPR). Thus, it becomes a real issue of how much DoD should direct when in fact, under many integration/CLS contracts, TSPR is a major requirement.

The government needs to weigh this against the potential that either the government moves away from CLS or a particular system on the contract changes or goes away. It is clear that as the acquisition/support strategy is being developed for either a new system or a legacy one, this issue must be addressed.

Notwithstanding this issue, however, we have found that many companies are moving to OSAs in some form, independent of any direction from the government. They are doing it for business reasons, the least of which is to be competitive.

The second factor that takes on significant importance, particularly in the case of legacy systems where full CLS is not implemented, is the issue of asset visibility. While the Services are taking significant steps to improve visibility under the Total Asset Visibility (TAV) program, there are real questions of adequate visibility at the inventory control points, air logistics centers, and other places. The problem is compounded by an extremely large number of stovepipe systems and the lack of shared databases.

OSD and the services must take action to ensure that they have visibility horizontally across these stovepipes and that they take advantage of IT technologies such as data mining and data warehousing to achieve shared data bases.

PROGRAM MANAGEMENT

The implementation of OSAs to improve supportability requires total management authority cradle-to-grave. One of the major factors in the success of the IEWCS program discussed earlier was the factor that the PEO had responsibility not only for new systems but for legacy systems as well, and was responsible for the total life cycle of those programs.

While the department has made great strides in addressing the total cost ownership on programs, it is clear that supportability must continue to be emphasized as an up-front requirement. In addressing supportability requirements where OSAs are not stand-alone solutions, other approaches such as COTS and commonality also influence supportability. In addressing the implementation of OSAs, the department needs to recognize that while this approach may help alleviate parts availability problems, the decision to implement OSAs must be considered in the context of overall maintenance and support concepts. This can only be successful if supportability is considered in its totality up front.

RECOMMENDATIONS

In spite of what many may perceive as the technical or programmatic hurdles associated with the implementation of OSA, the OSTF has concluded that the real challenges are in the management area. There are a number of actions that must be undertaken if we are to realize the full potential of OSA and commercial products in achieving focused logistics for JV 2010. These are:

1. The Program Executive Officer/Program Manager must be given total "cradle to grave" responsibility for their system/systems. The real success of a program depends upon having one person in charge that can address everything from requirement definition, development/technology insertion, and production to follow-on support. This was clearly a major element in the success of the Army IEWCS.

2. Establish a mechanism for transporting concepts/architecture/interface requirements across multiple platforms/services. At a lower level, the Joint Aeronautical Commander Group (JCAG) has accepted that task as it pertains to the implementation of the JTA and the lower level standards required to meet F^3I for aeronautical systems. There is clearly much more that can be done in this area.

3. Increase support for the work already being accomplished. This would not only include the initiatives underway within the JCAG, but also those initiatives/studies being accomplished by the OSTF.

4. Significantly increase our emphasis on improving logistics processes as well as eliminating/improving the logistic IT systems we have today. If we could do only one thing in this area, probably the most important initiative would be to implement the IT tools required to provide horizontal visibility across the multiple stovepiped system. This has to be done across all of the Services. To date, there is no joint or common initiative that would assure the level of visibility needed to support existing or future systems.

OBSERVATIONS ON THE JOINT TACTICAL RADIO SYSTEM

by Chris Waln

Introduction

Although small in scope, the JTRS program offers more opportunities to change the character of DoD communications systems than programs several times its size. In addition, with small to moderate changes, it can serve as an Open Systems (OS) Process exemplar.

In 2007, 80% of the communications force structure will be made up of legacy systems. Of the 20% new content, 80% is in less than major systems development. Of that 80%, 80% is addressable by JTRS – either in terms of development process or actual deliverable end-items. To be most effective from an OS Process perspective, some fine tuning to the program's role, scope, and management construct is required.

For JTRS to achieve true interoperability as envisioned in the OS Process, the JTRS Program Office must:

- Have a higher level of empowerment;
- Divest responsibilities which conflict with its "Plug & Play change agent" role; and
- Consider waveforms as well as technology insertion and supportability.

Management

The strategic context for JTRS needs to be made visible by explicitly tying the JTRS architecture process to Joint Vision 2010 (JV2010) interoperability demands, the JTA, and the C4ISR Framework. These ties are missing and this leaves JTRS looking like a management "best practices initiative" rather than a core program.

Service TOA should be transferred to the Army for execution under DAE auspices with fenced funding. The current contributive funding model has a long history of destabilizing programs, with late delivery the least of the negative outcomes.

As it is currently funded, JTRS funding is insufficient to support efficient and operationally relevant deliveries. Early funding should be increased by a factor to 1.5 to 2 to support parallel prototype deliveries to the test environment on 3 month centers.

The JTRS program compliance enforcement responsibilities are unsupported by effective control mechanisms and interfere with making the program a source of solutions for Service program managers. These responsibilities should be divested to the ASD/C3I technical staff

Fine Tuning the Planning and Architecture Development Activity

The tie between JTRS and higher/lateral communications architectures is weak. (Higher level architectures may be missing.) For JTRS to be included or referenced, the Program Office must actively participate in higher/lateral architecture development to include waveform development activities.

The Program Office has not identified a roadmapping tool and should do so. The potential complexity of successful outcomes demands it. Likewise, the Program Office's databases on Service radio modernization planning are largely unpopulated and what information and data are available are uncosted/unphased and may not represent the Service's positions. The financial leverage offered by JTRS cannot be broadly demonstrated without this information. This is a major collection effort, but it essential for overall program success. In a similar vein, there is no visible plan to target high visibility/high payoff opportunities first. The Program Office should develop a delivery schedule (by segment/domain) which supports early successes in the best understood areas.

Testable Prototype Executive Agent Role

The JTRS timeline for prototype deliveries is too slow. The schedule won't underwrite strategic business change (no sense of urgency); won't result in new radio deliveries in meaningful numbers in time; and can't demonstrate early successes before Administration change. Since effective strategic change is best built on a series of rapid-fire short-term success which ultimately blend into a long-term culture shift, prototypes should be delivered on 3 month plan (versus the 6 month plan, 12 month funding profile) to create the visible evidence of constant improvement.

The testing community is antagonistic toward the JTRS accelerated development approach. SECDEF/Legal relief from the usual testing methodologies should be granted. (Acquisition reform precedents exist).

Exit criteria for prototype readiness for test and prototype test success have not yet been established. The Program Office should start developing these criteria now using INTEROPERABILITY as the guiding principle, not slavish adherence to arbitrary standards.

Staff Commentator on Service Program Activities Scope

"Commentator" is a not a value-added role for the JTRS Program Office. The Program Manager works for the Army which puts the PM in an invalid position from which to comment on sister Service compliance, and the PM has no believable, explicit enforcement mechanism for dealing with non-compliant programs in any case. Making JTRS responsible for compliance monitoring casts the JTRS Program Office in a "cop" role when what is really needed is for JTRS to be viewed by PMs and Services as a valued resource. JTRS architectural compliance duties should be moved to the ASD/C3I technical staff and "fire-walled" from JTRS. JTRS should, however, lead the process of defining an explicit model for architectural compliance (entrance criteria).

The JTRS Program Office role (relative to other DoD agencies) in the communications standards process is undefined. The program should be the principal OSD POC for participation in the industrial radio standards dialog.

Conclusions

The Joint Staff should continually and consistently demand JTRS as a JV2010 enabler, for reasons of both capability and footprint. The JROC should use JTRS ORD as a model for other OS enabled capabilities. (The MNS should be waived -- radios aren't a mission). The Vice Chiefs should use JTRS as a comparable when reviewing other capability requirements before presentation to JROC. The Services should increase their participation in operational architecture development to take best advantage of JTRS implementations. The Military Departments should assent to TOA transfer to enable realistic JTRS execution. Industry should maintain its active participation in the forums, but should demand active government leadership.

The DAE should agree to make JTRS a 1D program for its leveraging importance to the Department. This should be a championship action rather than an increase in oversight. The DAE, ASD/C3I and SAEs should protect the program to ensure acquisition reform-based methodologies are given a chance to succeed. The Vice Chiefs, DAE, and SAEs must demand greater attention to supportability issues (assign a DPML). The DAE and SAEs should develop a two tier incentive structure. JTRS compliant programs should be given extraordinary acquisition process and budgetary process relief. JTRS responsive contractors should be given greater opportunity for performance-based profit. The DAE should seek legislative relief from testing processes which are JTRS(OS) unfriendly. ASD/C3I must take on the compliance monitoring role to prevent JPO from becoming "them." The OSD Comptroller should agree to putting funds in "D" program element and use the power of the PBD process (with the advice of DAE) to prevent stovepiped end-run programs.