Using the C4ISR Architectural Framework as a Tool for Assigning Management and Technical Responsibilities

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Abstract

Architectural views, as defined by the Department of Defense's (DoD) Command, Control, Communications, Computer, Intelligence, Surveillance and Reconnaissance (C4ISR) framework, are used as a prism to develop a management structure for implementing programs distributed across multiple organizations. This structure is also useful in managing smaller efforts within an evolutionary acquisition program. The paper recommends a matrix that defines management tasking across multiple management layers, and in terms of the three C4ISR architectural views. The matrix provides a template for assigning technical and programmatic responsibilities across organization levels and suggests where stakeholders should place their primary focus. Individual projects also are shown to each have zones of optimal technical enhancement that form a continuous improvement band in which systems may evolve and technology may be inserted to enhance system wide performance. The author applies this template to the Joint Tactical Radio System (JTRS) Joint Program Office (JPO) and discusses appropriate management focus within the context of the JTRS JPO's primary role as an integrating program management office charged with directing an evolutionary acquisition program.

Introduction

The Joint Tactical Radio System (JTRS) Program is a major DoD effort aimed at replacing virtually every radio and radio system within the Department. The program spans over two decades, and across all four Services. JTRS is an evolutionary acquisition effort and system capabilities will be fielded over time as technology enhancements become available. To manage this program of programs, the Office of Secretary of Defense (OSD) established a Joint Program Office (JPO).

The JPO's role is to manage the overall program across Clusters and to assure that the developed systems are interoperable and, in the long–term, integrated into a single networked communications system. The JPO is also responsible for developing waveform applications and the Software Communications Architecture (SCA) upon which the JTRS programmable radio is based. The Cluster managers are tasked to build systems for their assigned domains and to meet the requirements set forth in the

Operational Requirements Document (ORD) that pertain to their acquisitions. Program execution responsibilities are thus split among separate Cluster managers, the JPO, and other stakeholders.

Establishing the proper level of responsibilities and task sharing among the various organizations responsible for producing components of the JTRS is key to properly managing the program. JPO leadership must determine at what level within and across multiple organizations various responsibilities should be placed, as well as the specific levels of detail that should be addressed by different individuals within these organizations. Focus must be maintained, as managers and engineers work at different levels and with varied degrees of detail, to assure that each Cluster develops its part of the JTRS system within the overarching JTRS framework.

This paper will first briefly explain the evolutionary acquisition process identified by the May 12th 2003 Department of Defense Instruction (DoDI) 5000.2 as the acquisition method of choice. It will then explain the C4ISR Architecture, and illustrate its use within the DoD Architecture Framework V1. The JTRS program is then outlined and the C4ISR architecture views are applied. The paper also draws conclusions regarding the primary role of the JTRS JPO as the overall integrating program management office. Using the C4ISR views leads to developing a table that breaks down program responsibility and provides focus for program and project managers within the JTRS effort.

Evolutionary Acquisition and DoD Architectural Updates

On May 12, 2003, DoD issued new acquisition policy guidance, codifying many innovations and streamlining initiatives instituted within the Department over the last

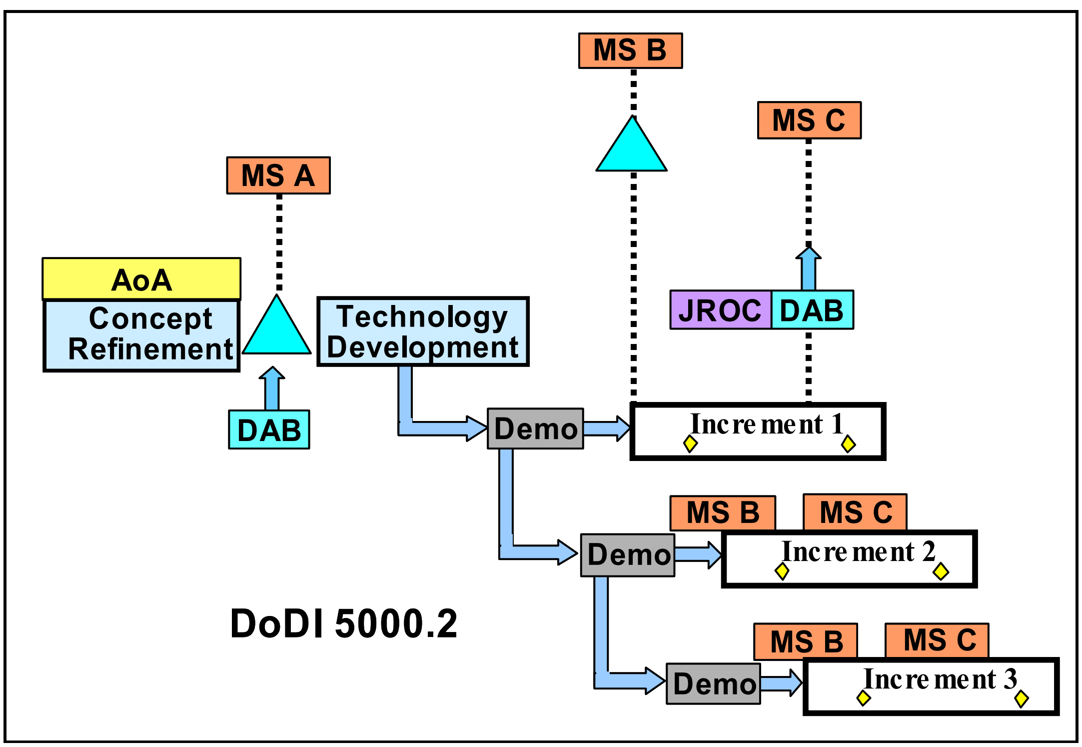

Figure 1

decade. The most sweeping change is a movement away from the traditional linear acquisition process that guided the DoD's acquisition policy since its inception. An evolutionary acquisition model was chosen as the preferred acquisition method for all DoD acquisitions. The model is pictured in, Figure 1, above, in a simplified illustration taken from the DoDI 5000.2. Remnants of the old linear system can be seen in the milestone (MS) A, B and C decision points. Specific elements of each MS review have been redefined within the current 5000.2 document. Within this new approach, programs are split into increments and each increment must pass its own MS B and C decision points. The Joint Requirements Oversight Council (JROC) and the Defense Acquisition Board (DAB) now review requirements iteratively within each incremental build and feed new or modified requirements and acquisition guidance back into the next incremental build. The chief evolutionary mechanism within this system is the injection of technology through demos, leading to each new incremental build. Now major programs may no longer have a constant set of requirements as defined within an Operational Requirements Document (ORD) or charter approved by the DAB. The process embraces change at all layers, from requirements definition to nonmaterial development (i.e., training, procedures, doctrine and tactics) and material acquisition. This process is monitored by Overarching Integrated Product Teams (OIPTs) that look to the integration of material and nonmaterial solutions with regard to material solutions, system requirements and integration issues within and between incremental builds.

This change in the DoD acquisition approach has fundamentally transformed the principal role of major program offices. The traditional program management functions (meeting cost, schedule and requirements across many projects within a particular program) must still be met as programs are implemented along each incremental build of an evolutionary acquisition effort. However, the program office must now manage a

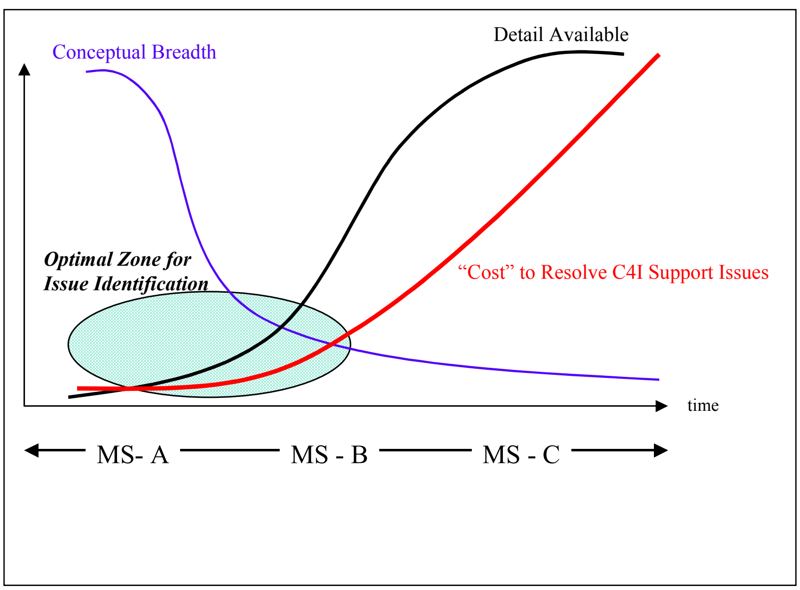

Figure 2

portfolio of programs across increments.

Figure 2 shows a well-known graph that depicts the relationship between project maturity and cost in making engineering design changes over time. The figure is based on a traditional acquisition process and its primary tenants hold true for all programs. As shown, at the beginning of a project there are many options for designers and conceptual breadth is great. At the same time, program details such as design parameters and specific system interfaces may be lacking. Since the engineering design is not yet well defined, changes can be accomplished with relatively low cost. Correspondingly, as time goes on, the design becomes better defined and more specific details are known with regard to system operation, interfaces and technical design. With time, the conceptual breadth or design options are reduced and any changes tend to cost more because redesigns require that new hardware must be built. From a single project or program perspective, there is a period that is optimal for design changes, given the available design detail and cost of change as depicted by the single oval in Figure 2.

As shown in Figure 3, each Cluster program within the JTRS acquisition effort matures at a different rate over time. This results in displaced and possibly overlapping zones of optimal engineering change for each Cluster program. Within the JTRS' evolutionary acquisition process, the JPO's primary challenge is to manage across Clusters and over time to smoothly enhance system capabilities in support of near-, mid- and long-term program objectives and requirements. By applying well-defined standards and specifications, the JPO must shape the JTRS program evolution within an overall architectural framework that provides for future enhanced capability and meets long-term Joint Vision (JV) objectives. The primary risks to evolutionary change are the likelihood that a Cluster will design and build a system element that blocks this future growth

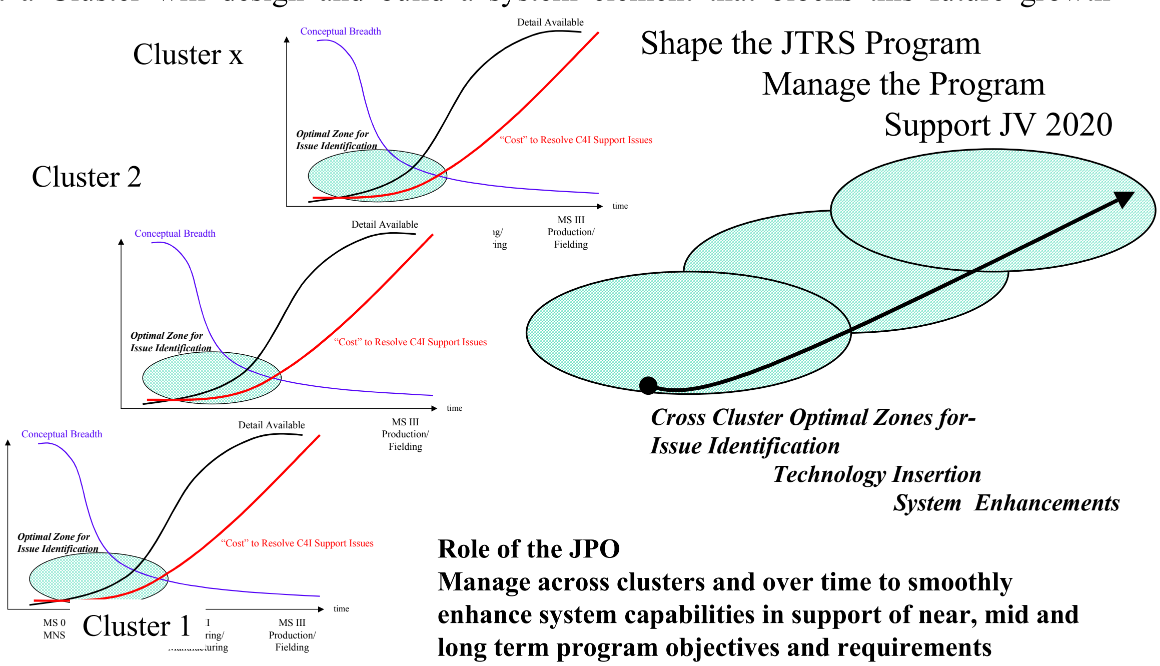

Figure 3

capability, or that incremental requirements could move system capabilities away from the overarching JV objectives.

The preceding discussion has focused on Clusters because of the unique challenge posed by multiple programs within the JTRS acquisition program. The challenge is even greater when one realizes that each Cluster may, as part of its own multi-service acquisition program, be an independent evolutionary acquisition effort with its own incremental development schedule. The high-level management goal is still the same: managing change to foster the orderly evolutionary development of the overall system. The key is to properly manage the continuous zone of evolutionary system enhancement. As seen in Figure 3, this zone is formed by the overlapping of individual project zones of optimal change.

At a portfolio management level, the principal role of the integrating program manager is managing this change and assuring that decisions made within each increment allow for continued product improvements within the evolutionary acquisition process. Project and program managers must now be attuned to strategic issues and long-term considerations as they manage across shorter-term incremental builds.

The C4ISR architectural framework (now integrated within the draft OSD Architecture Framework V1) provides an excellent tool for viewing various parts of a program. As will be shown below, the C4ISR views provide a structure by which technical and program managers may analyze a system. Each C4ISR view allows managers to decompose elements of the program into logical blocks, based on what portion of the program is being worked. The remainder of this paper will look at the C4ISR views and how they may be applied to manage a large evolutionary acquisition program across multiple incremental builds--and in the case of the JTRS program, multiple Cluster acquisition efforts.

Defining the C4ISR Views

In December 1997 the DoD C4ISR Architecture Working Group, under the auspices of the Directorate for C4I Integration (now call Network and Information Integration Office / NII), published a final report defining a framework for C4ISR systems. This report is the second iteration of the DoD sponsored framework and is widely accepted throughout DoD. The framework provides the strategic definition and underlying means to view all C4ISR architectures within the DoD. Its major elements are depicted in Figure 4 below. The Institute for Electrical and Electronic Engineers (IEEE) defines architecture, in IEEE 610.12, as the organizational structure of a system or component, system or component relationships, and the principles and guidelines governing design and evolution over time. The DoD has implemented this definition by specifying the interrelated set of architectures depicted in Figure 4 above. These architectures are defined in version two of the DoD framework as “Operational,” “Systems,” and “Technical”. Figure 4 also shows the relationship among these architectural views. The definitions from the C4ISR Architecture Framework V2.0 are provided below to ensure a common understanding of each view.

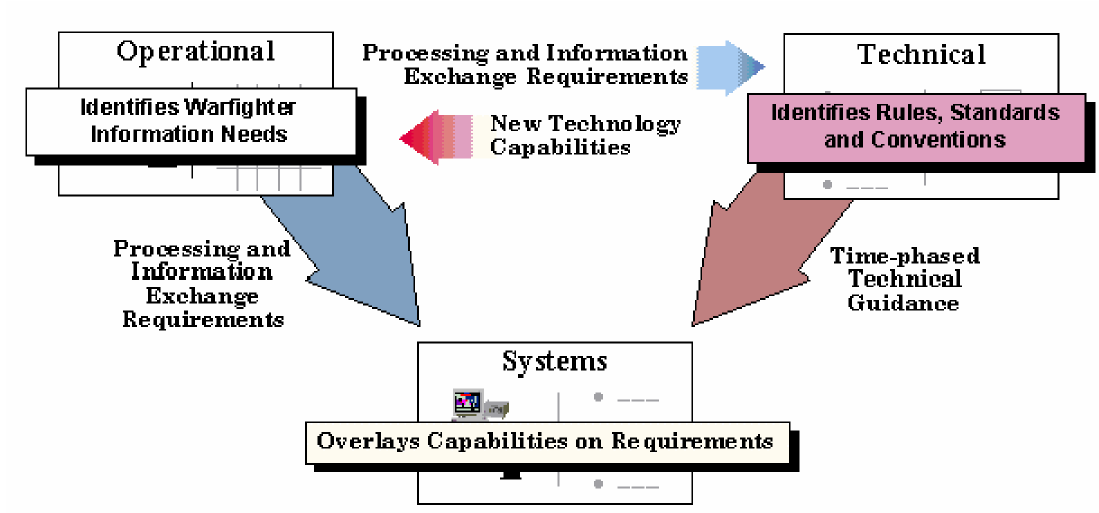

Figure 4

- *Operational View* (OV): A description (often graphical) of the operational elements, assigned tasks, and information flows required to accomplish or support the warfighting function. It defines the type of information, the frequency of exchange, and the tasks supported by these information exchanges. [1]

- *Technical View* (TV): A minimal set of rules governing the arrangement, interaction, and interdependence of the parts or elements to ensure that a conformant system satisfies a specified set of requirements. The technical architecture (view) identifies the services, interfaces, and standards, and their relationships. It provides the technical guidelines for implementing systems upon which engineering specifications are based, common building blocks are built, and product lines are developed. [1]

- *Systems View* (SV): A description, including graphics, of systems [2] and interconnections [3] providing for or supporting warfighting functions (C4ISR ITF Integrated Architecture Panel, 18 December 1995). The SV defines the physical connection and location; identifies the key nodes, circuits, networks, war fighting platforms, etc.; and specifies system and component performance parameters. It is constructed to satisfy Operational Architecture (view) requirements per standards defined in the Technical Architecture (view). The SV shows how multiple systems within a subject area link and interoperate, and may describe the internal construction or operations of particular systems within the architecture. (C4 Chiefs Consensus SA Definition, 12 January 1996, as modified at the suggestion of the USD (A&T) community). [1]

The C4ISR architecture also forms the basis for the DoD Architecture Framework Version 1, published in draft form on 15 January 2003 and recently approved for use via OSD Memorandum, February 9, 2004, Subject: The Department of Defense Architecture Framework (DoDAF). Figure 5, below when compared with Figure 4, above, shows that

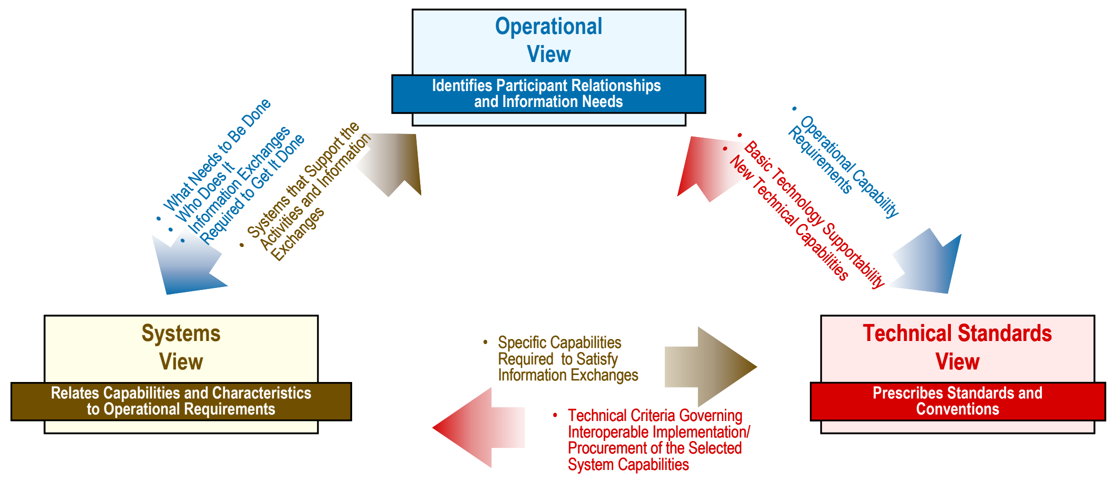

Figure 5

the draft DoD Architecture V1 closely parallels the older C4ISR architecture V2. The application of the C4ISR framework to the more general DoD framework illustrates the broad applicability of the C4ISR architecture. The DoD V1 architecture is anticipated to eventually eclipse the original C4ISR framework. However, the C4ISR framework remains more widely known, and the relevant portions of the two frameworks are essentially the same. Therefore the remainder of this paper will use the C4ISR architecture as the framework to organize a large distributed program management office structure.

System Definition

The C4ISR architecture's ability to act as a decomposing prism for complex communications systems is extremely useful in developing and managing those systems. Figure 6 depicts the components that describe a complex system such as the JTRS. It is based on DoD guidance as explained in the C4ISR Architecture and tailored for the JTRS program. As with any complex system, the JTRS is composed of Hardware, Software and supporting Architectures. Specifications tend to drive the engineering design, whereas standards tend to drive the engineering approach. Architectures tie together hardware and software; hence, both standards and specifications tend to drive architecture definitions. Together, software, hardware and supporting architectures completely define the JTRS.

The JTRS may be decomposed into its component hardware, software and architecture elements as depicted by the top set of circles in Figure 6. A single JTRS component is

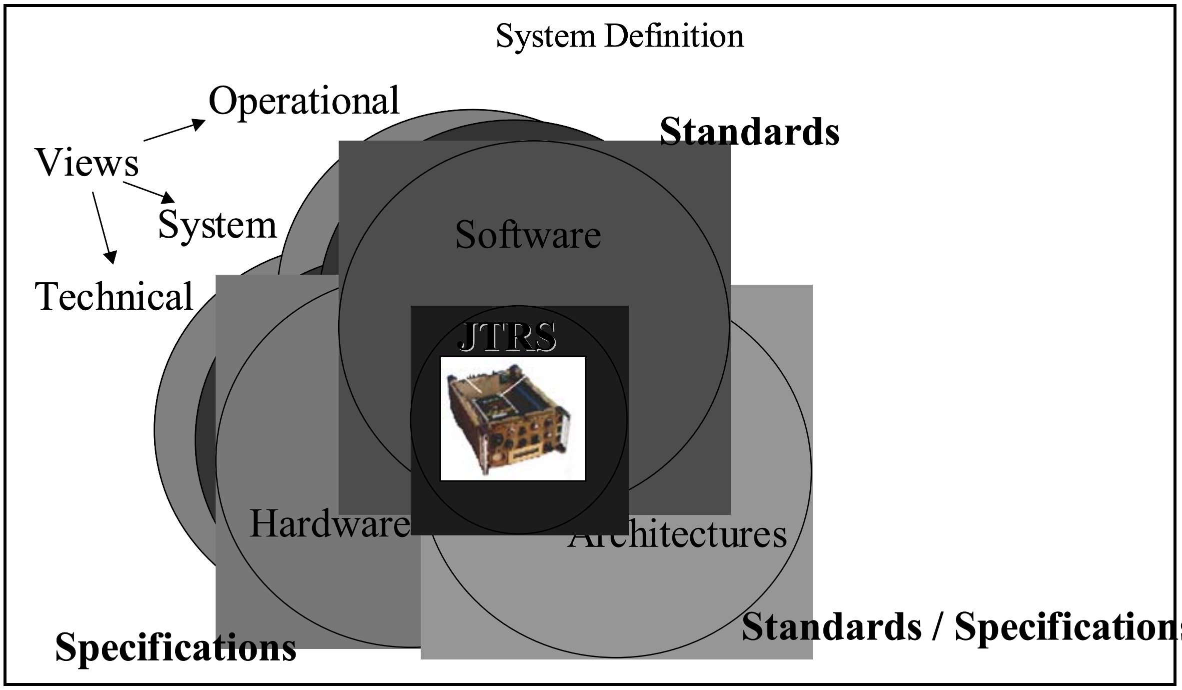

Figure 6

depicted within the overlapping circles and is defined by its hardware design, loaded or imbedded software, and internal architecture design. The JTRS is made up of multiple components networked together within a unifying architecture. The JTRS can be viewed at varying levels of complexity and detail, based on the C4ISR view used. These views are interrelated, and together they form a complete picture of a system or end item. Each view can be thought of as a separate color screen used to form a full-color picture. When each screen is separated (i.e., into red, green and blue) the picture becomes decomposed and information concerning each color component is discernable. However, when overlaid, a full color picture can be seen. Each color separation may be adjusted independently of the others; however, the final color balance of the picture is related to the interaction of each color separation. We will next address the use of these views to guide management emphasis within a program.

Levels of Management

Each view of the C4ISR Architecture (operational, system & technical) attempts to explain interrelationships from a slightly different focus and level of detail. When moving from the operational view towards the technical view, the focus tends to narrow, as technical detail tends to increase. However, within each view the perspective remains constant. Within the operational view, requirements, mission and system interfaces tend to be the items of interest. The system view usually examines “box” or component interrelationships, including component interfaces, while the technical view is concerned with the proper implementation of standards and specifications to meet technical interoperability and component design. These views thus define areas of interest and serve to focus managers' and engineers' efforts, depending on what view is under consideration.

As an example, when dealing with a component at the level of contract management, design engineers are primarily concerned with standards and specifications that tell how the component is built. At the system level, the technical focus is at interfaces between

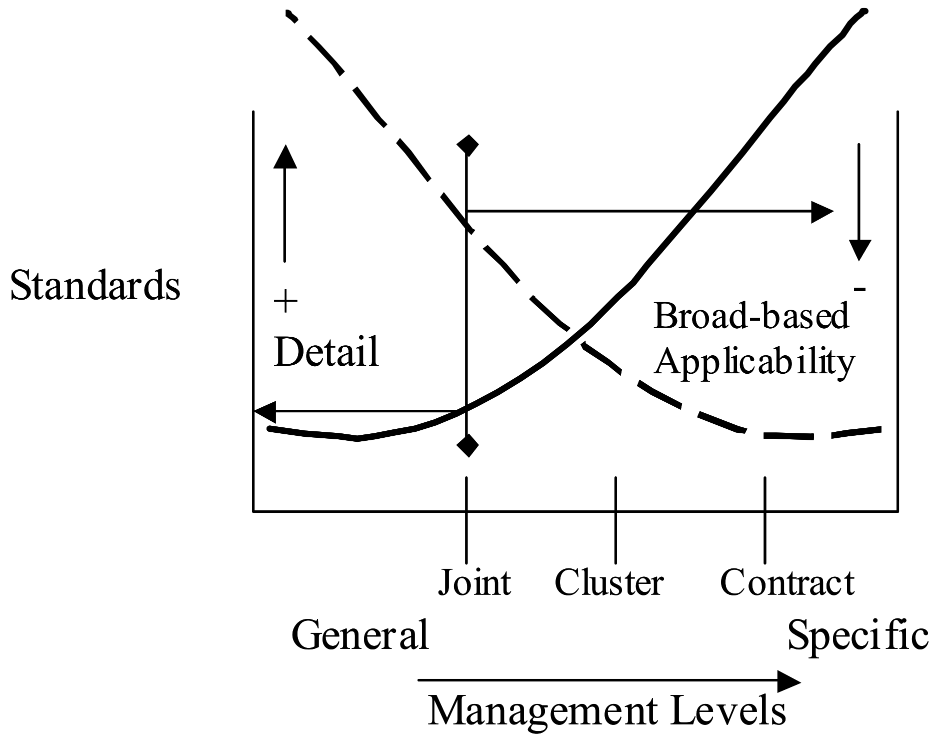

Figure 7

components and the network. In the JTRS, component sets are tied together into a complete system at the systems level. System level concerns deal with traditional systems engineering functions, and products at this level tie detailed engineering efforts at the technical level to overarching and general descriptions at the operational level. The system level architecture allows components described in the operational view to be appropriately integrated into a complete system.

Understanding how much detail to apply to standards and specifications at each level of management is critical. Figure 7 shows the level of detail (solid line) and the applicability (dashed line) of standards at three generalized management levels. From a JPO perspective, standards describing the JTRS will be less detailed and broadly applicable across the Joint arena. However, at the contract level, standards or specifications may be very specific and more numerous, but not applicable across the entire system.

Lack of common terms across the engineering and acquisition communities may create confusion. For example, a programmable radio set may contain sub-components that are tied together within a component box. Each sub-system may have its own system and technical level descriptions, and the interconnection of these sub-systems would be designed according to some interface architecture. A program manager focused solely on this single box may have projects for each of the sub-systems and may manage interface requirements between sub-systems through system and technical level views of the entire radio set. At a higher level of management, multiple sets may be part of a larger JTRS networked system. Technical standards for each set may form the basis for interface requirements between major components within the JTRS system. It is at this higher level of systems management that the C4ISR framework is most useful. Looking back to Figure 6, we can imagine multiple illustrations depicting any level within the entire JTRS system. At the enterprise level, a network of multiple radio systems may be pictured in place of the single radio set illustrated. Figure 8 illustrates the above discussion.

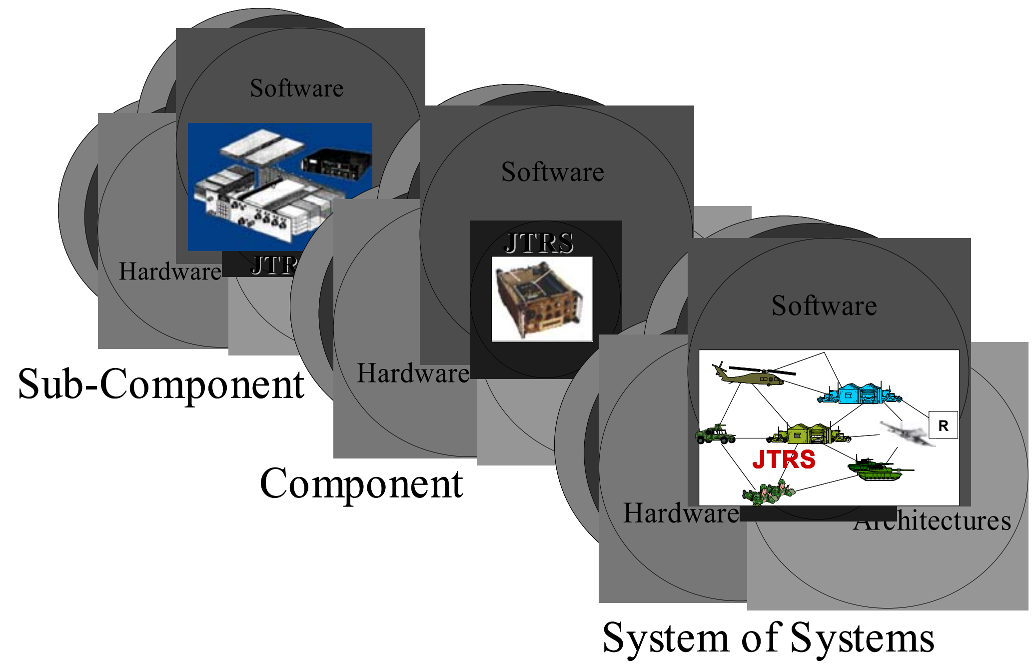

Figure 8

The JPO's or integrating program management office's role is most critical at the enterprise level. It is only at the enterprise level as depicted in Figure 8 as a, "systems of systems," that the evolutionary build between major clusters can be managed. At this level, system definition and functionality are managed over time through the proper use of standards and specifications at each level (JPO, Cluster (multi-service) and individual contract), and through configuration management between levels. The role of the integrating program office (in this case the JTRS JPO) becomes the management of a portfolio of programs whose collective purpose is to provide an integrated system. Subsequent discussions within this paper focus on the enterprise system level management of complex programs.

The technical, system and operational views of the C4ISR framework parallel the above management levels shown in Figure 7 and thus provide a means to guide the level of detail associated with each decomposed C4ISR layer. For example, from a technical view, both hardware and software specifications and standards will be very detailed. Architectural elements will also be correspondingly detailed. As one moves from the technical view to the systems and, finally, the operational view, the level of detail decreases. Typically, operational level views are cartoon-like, whereas technical views tend to be detailed listings of specifications and standards that define components of the system, but do not provide a "picture" of what the system looks like.

The Management Matrix

Table 1 highlights specific focus areas for contract, Cluster and joint managers and shows where they should focus their attention based on the C4ISR views and their respective management levels in the organization. Some focus areas repeat between organizational

C4ISRView Based Focus Matrix

Program Relationships		C4ISR Views		
Management Level	Organizational Level	Operational	System	Technical
Joint & Cluster	OSD	X	X	
Joint	Operators	X		
 Joint Contract	Joint PO Oversight Execution	 X +	 X X	 X
Cluster	Cluster PO	+	X	X
Contract	Contract Efforts	+		X

+ ↑ Widening Interest

Table 1

levels as a result of overlapping structures in the C4ISR framework and its widening areas of interest as one moves from detailed contract management to the Joint level of management.

The C4ISR views provide program management a context from which to develop plans for program execution. At each management level, staff should focus on items primarily associated within the corresponding "Xed" C4ISR views. The "+" marks indicate the need for all levels of management to know and understand operational requirements (but the item is not the primary consideration at that particular level of management). The level of technical detail increases as one moves from Joint through Cluster to Contract levels, while the details of military operations lessen. Conversely, as one moves from detailed technical views to more general operational views, the details concerning operational considerations increase.

Looking at an area of overlap, Cluster managers share their focus on the systems view with both JPO and OSD organizations. This overlap provides a linkage between detailed specifications and standards at the contract level and system-wide operational requirements at the Joint level as described in the OV. Looking now at the top Joint & Cluster level, OSD provides general acquisition oversight through assigned Service Acquisition Executives (SAEs). This means that at the OSD level managers or engineers should be primarily concerned with operational and system level views of the overall broad product and its connecting architecture.

The JPO's dual roles as both an oversight and a program execution agent require it to work within all the C4ISR views and to focus at specific levels within the matrix based on the management role being preformed. Waveform application development and SCA management are natural outgrowths of the JPO's responsibility for overall joint program oversight. However, the execution of the waveform program requires detailed contract level management of projects that lead to product delivery of software end items. The JPO is uniquely positioned to also provide program-wide configuration management across clusters and individual contract efforts. For example, standards and specifications are used to completely define systems, especially at the technical level. Contract managers also develop system specifications and standards through their contract efforts. Performance specifications are developed at the joint and Cluster level. The responsibility for overall system integration resides with the integrating program office (in this case, the JPO). Therefore, the overall configuration management (CM) for all levels of specifications and standards must reside with the JPO.

Importance of the Approach

The layered approach to technical management described is critical when managing a portfolio of programs at the integrating Program Management Office level. One of the chief challenges in maintaining the proper focus at the highest levels of management is the ability to work detailed technical issues, without getting mired in the low level execution of individual programs and projects. At the same time, managers and engineers also need to know when not to step down into individual programs and project execution because of the risk of losing the strategic perspective required for the management of a portfolio of programs. The use of Table 1 to set management and technical focus is helpful in assessing the proper focus of management or technical effort given one's place within an organization. Table 1 may also be used in managing multiple programs that are at different phases within their program cycles.

The C4ISR framework and Table 1 also plays an important role in defining the organizational focus for programs managed at the integrating program office level. Figure 2 shows that over time the technical definition of the program increases as program flexibility decreases. Thus as programs within a managed portfolio mature, different aspects of the architectural views will be more important than others. Control of the continuous zone of evolutionary system enhancement depends upon coordinated control of operational, system and technical level views over time. Using the management matrix in Table 1, program personnel can properly adjust their technical focus based on where they sit in an organization and the maturity of a particular program.

Conclusions

This paper demonstrates that the architectural views defined by the DoD's Command, Control, Communications, Computer, Intelligence, Surveillance and Reconnaissance (C4ISR) framework work well in developing a structure to manage multiple programs and projects distributed across diverse organizations and agencies. The C4ISR framework is used to provide guidance for the approriate level of effort and focus for program and project managers at various levels within a multi-organizational program. This supports development of a management matrix that defines a suggested level of effort in terms of the three C4ISR architectural views across management layers. This matrix provides a template for assigning technical and programmatic responsibilities across multiple organization levels, and suggests the primary areas of focus for each stakeholder and project manager, given their places within the organizational structure and the current phase of a particular project. Overall focus is determined with the understanding that an evolutionary system-wide development effort is accomplished through managing overlapping individual project zones of optimal engineering enhancement. At the JPO (or integrating program management office) level, the focus for an evolutionary acquisition program is on managing this continuous zone of enhancement to allow an ordered growth in capabilities over time.

End Notes

[1] These definitions are extracted from the C4ISR Architecture Framework. The definitions and the products required by the framework focus on information technology. However, the concepts described can be applied to a wide range of technologies. The most recent update to the C4ISR adopted the idea of "Views" as opposed to three sub-architectures.

[2] Systems: People, machines, and facilities organized to accomplish a set of specific functions (FIPS PUB 3), which cannot be further subdivided while still performing required functions. Includes the radios, terminals, command, control, and support facilities, sensors and sensor platforms, automated information systems, etc., necessary for effective operations.

[3] Interconnections: The manual, electrical, or electronic communications paths/linkages between the systems. Includes the circuits, networks, relay platforms, switches, etc., necessary for effective communications.

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