C⁴ISRT in an Operational Context

Christine Salamacha, Sterling Smoot, and Kathleen Farris

On the morning of 16 January 1991, allied forces surgically bombed Iraqi military targets, marking the emergence of sophisticated U.S. technology and a need for greater interoperability among the services. The success of U.S. Central Command relied heavily on the ability of separate command units to quickly and accurately share planning information and execute operations. The debut of new weapons and the culmination of various theater-wide resources (e.g., high-tech precision guided weapons, sensors, unmanned airborne vehicles, and global communications systems providing "reach-back" capabilities) demonstrated a true need for a robust Joint Command, Control, Communications, Computers, Intelligence, Surveillance, Reconnaissance, and Targeting (C⁴ISRT) "family" of systems. This article describes the methodology and characterization of C⁴ISRT for a specific warfare area and two platforms involved in multiple mission areas. These environments are a subset of the Design Reference Missions that were sponsored by the Navy to improve the system acquisition and engineering development process of the future. (Keywords: C⁴ISRT, DRM, Operational context, OPSIT.)

INTRODUCTION

A Design Reference Mission (DRM) defines a threat and operational environment for a particular platform, system, or "family" of systems. As a "living" document, a DRM is intended to be used and updated across the entire life cycle of an acquisition program, from early concept and requirements development, through systems engineering trade studies and design evaluations, to final design validation and deployment. APL has developed a number of DRMs for its Navy sponsors. By design, these missions have a common structure composed of operational situations (OPSITs) that include a characterization of Command, Control,

Communications, Computers, Intelligence, Surveillance, Reconnaissance, and Targeting (C⁴ISRT). APL's DRM development process is discussed by Skolnick and Wilkins elsewhere in this issue. This article focuses on how the DRM C⁴ISRT development process parallels the larger DRM development process in both form and function. In particular, C⁴ISRT is addressed in terms of the specific warfighting objectives outlined in the DRM.

The current family of DRMs includes scenarios and OPSITs developed for specific platforms, warfare areas, and battle group/battle force elements. All of these

DRMs view C[4]ISRT as an enabler for warfighting missions and characterize C[4]ISRT in terms of the combat activities it supports. They differ, however, in terms of fundamental operational perspectives and objectives, with resulting differences in C[4]ISRT emphasis. The various approaches and processes for including C[4]ISRT are illustrated in this article for three DRMs: the next-generation land-attack destroyer (DD 21), Theater Air Defense (TAD)/Area Air Defense Commander (AADC), and next-generation aircraft carrier (CVNX).

A COMMON DRM PROCESS

As already noted, the C[4]ISRT development process (Fig. 1) mirrors the larger DRM development process in both form and function. The goal of both is to identify and appropriately characterize the external operational characteristics of a scenario in order to create an environment that stresses the key performance parameters identified for the systems under consideration.
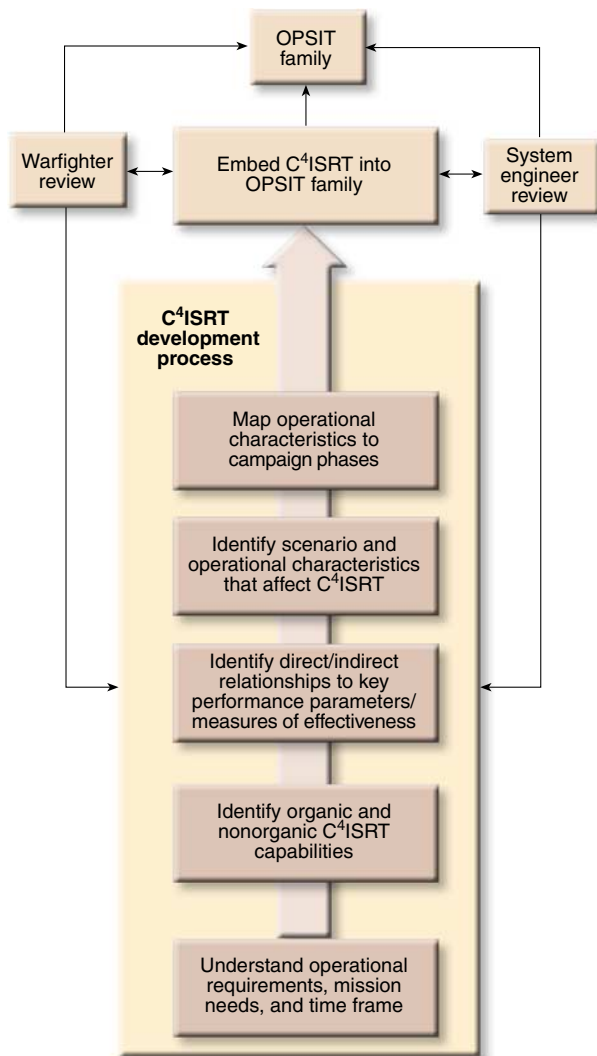
The DRM development process begins with an analysis of operational requirements, which are typically based on an Operational Requirements Document, often in draft form. In lieu of an Operational Requirements Document, missions are derived from Capstone documents, mission need statements, and/or program office and subject-matter-expert input. From these sources, key performance parameters are identified which are then used to help identify C[4]ISRT parameters that impact the system. These parameters are all noted, and a means of expressing them within the operational context is devised.

The primary components of an OPSIT are depicted in Fig. 2. These elements define the basic structure within which specific operational characteristics, key performance parameters, and C[4]ISRT are addressed. C[4]ISRT considerations are represented in all OPSIT components.

ASSESSING THE IMPACT OF C[4]ISRT

Again, an understanding of the mission at a campaign-level and of C[4]ISRT supporting operations is a prerequisite to identifying elements of the operational characteristics that are expected to be key performance parameters. The successful identification of a significant set of operational characteristics relies on close collaboration between DRM developers and subject-matter experts to properly characterize the missions,
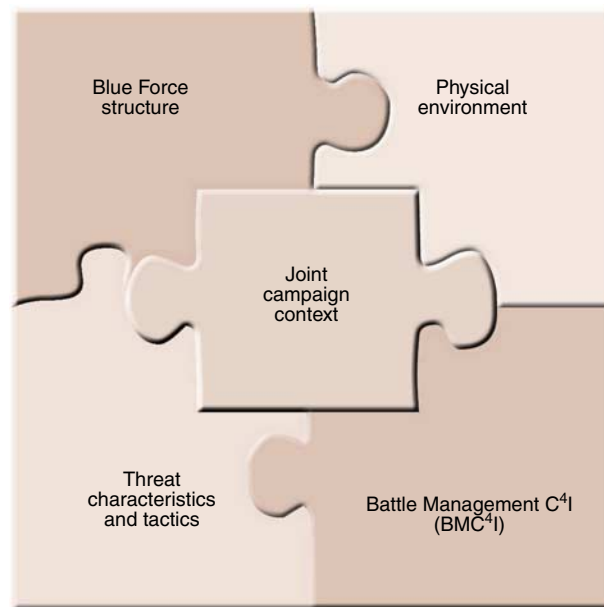

Figure 1. C[4]ISRT OPSIT development process.

Figure 2. Primary components of an OPSIT. (See the article by Skolnick and Wilkins, *Technical Digest* **21**(2), for a detailed discussion of these components.)

functions, and vulnerabilities embodied in the operational requirements.

The C[4]ISRT OPSIT methodology (Fig. 1) includes identifying organic and nonorganic C[4]ISRT capabilities necessary to support warfighting missions throughout the campaign phases of war. (Organic capabilities are assets located in theater and/or aboard the platform; nonorganic capabilities are assets not located in theater and/or not aboard the platform.) These C[4]ISRT capabilities are in turn examined for their relationships, direct or indirect, to the key performance parameters specified for the functional systems under consideration. This enhanced understanding of the role of C[4]ISRT in the context of the DRM enables DRM developers to better define the appropriate set of operational characteristics.

In terms of force employment, C[4]ISRT capabilities are provided by systems located in theater or in the continental United States (CONUS). The systems include space, air, ground, and sea assets of both the United States and its allies. The inclusion of specific C[4]ISRT systems and capabilities depends on the time frame specified in the DRM (circa 2000, 2010, 2015, etc.). DRM developers may specify additional assumptions regarding the availability of C[4]ISRT assets identified within an OPSIT to address specific C[4]ISRT support requirements.

Force employment also includes the definition of force command structures, both friendly and enemy. Friendly forces include Joint Task Force commanders and their staffs, service component commanders (e.g., Joint Force Maritime Component Commander), and naval warfare area commanders. In the evolving network-centric warfare[1] environment, the actual location of an individual command element is becoming less important, with commanders potentially located in CONUS or at great distances from their area of responsibility.

Connectivity requirements associated with creating and sustaining situational awareness at all levels of command in support of planning, coordination, and execution activities add to the demands of a C[4]ISRT infrastructure identified in the OPSITs. In general, the positioning of Blue, Red (enemy), and White (neutral) forces is primarily driven by operational considerations. The OPSIT developer may position combat elements specifically to establish a framework for assessing connectivity between command elements and their subordinates, as well as between units in the battle force. Line-of-sight versus over-the-horizon connectivity is among the communications-related concerns that can be addressed through the judicious positioning of units.

Another critical aspect of C[4]ISRT operational characteristics is the mapping of environmental conditions to C[4]ISRT systems and capabilities, identifying both nominal and stressing situations in terms of their effect on C[4]ISRT system performance. Environmental factors include natural and man-made phenomena. Natural factors that impact sensor and communications performance include weather (e.g., degradation of satellite communications performance due to rain attenuation) and time of day or night. The operational environment can also be affected by events such as attacks and Blue Force decisions and activities (e.g., force flows). Man-made factors affecting the environment include nonhostile electronic emissions (e.g., white transmissions including TV/radio, etc.) and deliberately generated hostile emissions. Yet another aspect of the man-made electronic environment is the unintentional overloading of communications resources by Blue Forces. (It should be noted that a criticism of many scenario-based analyses of warfighting effectiveness is that C[4]ISRT performance is assumed to be perfect, with unlimited bandwidth. This is clearly not the case.)

The definition of the C[4]ISRT operational environment includes a baseline understanding of projected connectivity among command elements, operational facilities, weapons-equipped units, etc. This common set of assumptions regarding the projected communications infrastructure includes a specification of the nominal performance attributes of communications services and the mapping of information products to information services (e.g., Integrated Broadcast Service) and data links. Ideally this specification of the projected communications infrastructure would be available from other sources and could be accomplished by referencing existing documentation. The degree to which the communications infrastructure is specified will vary by DRM.

After the previously described process, the complete set of required operational characteristics is mapped to a set of OPSITs referred to as the OPSIT family. These OPSITs will contain the required combinations of operational characteristics that appropriately stress C[4]ISRT systems. In an iterative process, OPSIT options may be discarded and requests for additional characterizations made.

In addition to identifying C[4]ISRT-motivated operational characteristics and defining the C[4]ISRT operational environment, an understanding of future operational trends and evolving concepts, common across DRMs, must be considered. For example,

- Command structures are becoming more distributed, relying on collaborative planning among the various distributed structures. Evolving network-centric concepts include the assumption that decision makers will have direct access to information across the battle space, allowing for fewer intermediate command elements within the organizational structure and decentralized decision making.

- The overall interest in network-centric concepts made feasible by advances in information technology poses C^{4}ISRT characterization issues, e.g., defining network configurations in terms of information services, addressing the impact of bandwidth allocation limitations, understanding the meaning of graceful degradation in a network-centric environment, etc.
- The increasing emphasis on manning reductions has C^{4}ISRT implications in terms of increased reliance on "reach-back" capabilities (in particular, those supporting the collection and processing of intelligence data) and automated systems. The term reach-back describes an in-theater combat element that draws on information and databases from CONUS and/or other out-of-theater sources.
- The deployment of longer-range weapons and precision guided munitions will have a significant effect on situational awareness, deconfliction, and targeting by simultaneously expanding the battle space and intensifying the data requirements for targeting within that space.
- The increasing importance of Information Operations—and, in particular, Information Warfare—may require that Information Warfare be portrayed as a warfare area unto itself as well as an enabler for other warfare operations (e.g., Strike Operations, Surface Warfare, etc.).

CONTRASTING DRM C^{4}ISRT EMPHASES

Although the generic C^{4}ISRT methodology is common to all DRMs, its emphasis reflects the unique perspectives of the particular Platform, Battle Force, or Warfare Area DRM. The primary emphasis of a Platform DRM is the ability of the platform to perform operations, both combat and noncombat, in support of its missions. Combat operations include explicit warfighting tasks such as radar surveillance and weapons firing as well as support activities such as replenishment. Noncombat ("quality-of-life") operations include crew medicine, crew correspondence (e.g., e-mail home), remote training, etc. Operational requirements pertaining to warfighting missions assigned to the platform are illustrated within the context of a continuous workload that includes both combat and noncombat activities. The availability of nonorganic C^{4}ISRT assets is determined at a command level above that of the platform, and the Platform DRM emphasizes how the platform performs its assigned missions using organic resources complemented by nonorganic resources.

The Battle Force DRM addresses the coordination of multiple battle force assets, often of Joint services, and applies these assets against all warfare area demands (e.g., Air, Surface, Information, and Strike Warfare, etc.) within a given conflict. Interoperability is a primary focus, with a strong emphasis on collaborative planning and coordination across warfare areas and the execution of plans and generation of subsequent tasking. Adding to the complexity is the broad range of situational awareness requirements associated with battle force commands. Interoperability and situational awareness are further complicated by issues regarding the releasability of information to allied and coalition forces. All of these issues represent stresses on C^{4}ISRT resources.

Warfare Area DRMs have a narrower focus than Battle Force DRMs in that they involve the collaboration of multimission platforms to address a specific warfare area such as TAD. Similar to the Battle Force DRM, emerging solutions to TAD and other warfare area challenges hinge on the extensive real-time/near–real-time exchange of information among diverse elements in and out of theater via extensive network systems. A Warfare Area DRM may reflect the perspective of a specific commander, as in the case of the TAD DRM which has a stand-alone annex dedicated to AADC. Whereas any Warfare Area DRM must address coordination and execution of specific engagements and the use and sharing of assets (including C^{4}ISRT), the AADC Annex also emphasizes the development of plans and the dissemination of those plans among combat elements supporting the TAD warfare area. It is to date the most comprehensive DRM effort addressing command and control issues. Similarities and differences in DRMs are illustrated by the following case studies of Platform, Warfare Area, and Battle Force/Group DRMs.

DD 21: Platform DRM

APL developed the DD 21 DRM as an integral part of the government's solicitation to industry for design proposals for the new Land Attack Destroyer. This DRM provided help in communicating the intended government use of the ship. As stated in the preface to the DD 21 DRM,

> [T]he Operational Context is described for both discrete events and continuous workload, reflecting the ship workload required by routine, transition and warfighting operations. The discrete events allow the Government to understand how particular aspects of a DD 21 design, such as survivability or weapons system performance, meet the Operational Requirements Document. The continuous workload activities allow the Government to understand how the DD 21 designs respond when stressed by simultaneous activities and degraded states of system capability.

C^{4}ISRT resources, both organic and nonorganic, support the ship workload requirements described in the DD 21 DRM.

Communicating the government's perspective did not include assuming or proposing design solutions, and much consideration was given to preserving design trade space, especially for C^{4}ISRT capabilities. The

DD 21 OPSITs emphasize tactical warfighting operations and, implicitly, C[4]ISRT functions supporting those operations. Overall, the explicit assignment of C[4]ISRT functionality to the DD 21 was handled carefully so as not to unintentionally constrain design trade space. Although OPSITs may specify the use of a particular C[4]ISRT asset in order to address a specific operational requirement, OPSITs in general are "solution free" to allow design trades.

DRM OPSITs capture stressing conditions inherent in simultaneous engagements. To represent overall platform demands on C[4]ISRT assets, both organic and nonorganic, the DD 21 DRM describes platform workloads that include activities and tasks performed on a continuous basis, as well as warfighting activities associated with discrete/simultaneous engagements. These concepts are depicted in Fig. 3. DD 21 was the first DRM effort to incorporate the concept of a continuous workload into its characterization of C[4]ISRT. It was also the groundbreaking effort for addressing C[4]ISRT requirements across warfare areas and for providing an operational context for information superiority concepts.

TAD/AADC Annex: Warfare Area DRM

The TAD/AADC Annex DRM provides an operational context for TAD operations. It supports the systems engineering process and stresses the key performance requirements identified in the Operational Requirements Document for the AADC Support System. The support system is responsible for aiding the AADC staff in both the planning and execution of Theater Air and Missile Defense operations, such as

- Maintaining situational awareness with a continuous assessment of both the air defense capabilities and air defense requirements of forces in theater
- Efficiently managing air defense forces (communicating with both subordinates and higher command centers, e.g., the Joint Force Commander) with timely alerts, warnings, orders, messages, and plans
- Collaboratively coordinating plans and intentions with other component commanders

To accomplish these tasks, the AADC must quickly and collaboratively share information with a broad number of command elements throughout the theater (Fig. 4). The Air Defense Plan (ADP) is the primary mechanism through which the AADC manages forces in theater. The planning process must be responsive to the needs of the air defense planners. Simultaneously, the AADC system must support real-time air defense tactical operations, which include monitoring both the air defense engagements occurring anywhere within the entire theater, as well as the health, stationing, and status of defensive assets in theater. The ADP describes the essential elements for conducting and planning air defense operations and provides the information that allows commanders—separated by great distances and operating under multiservice (and possibly coalition command) structures—to execute remotely, with little or no intervention.
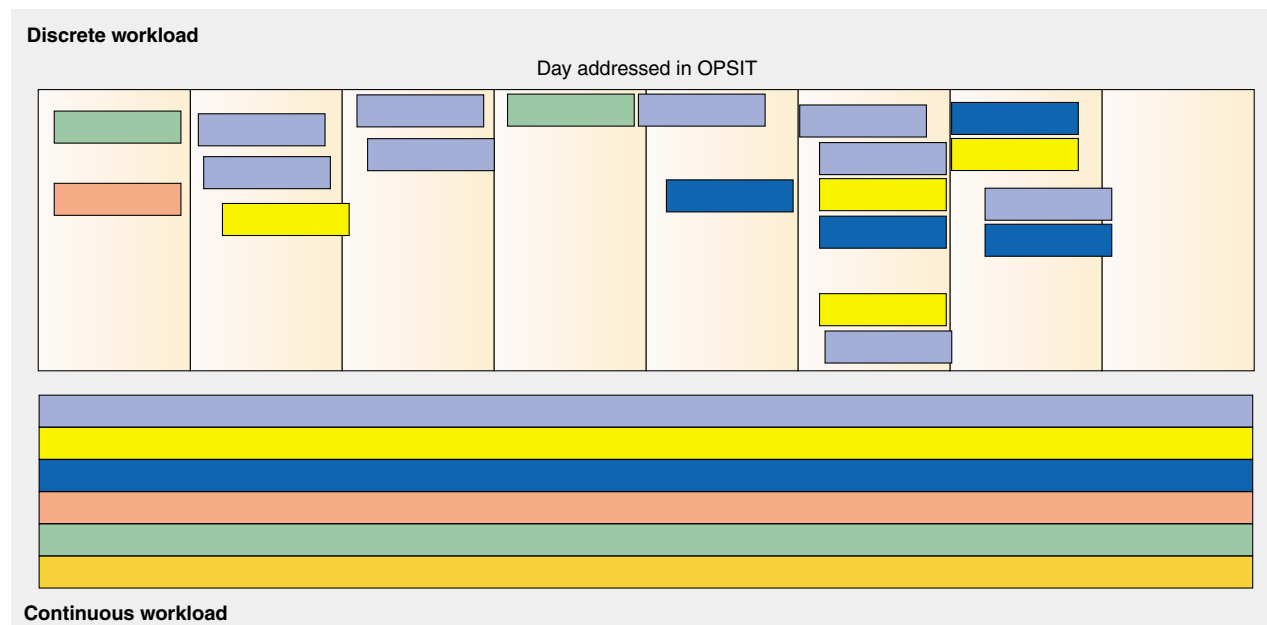

Figure 3. Notional DD 21 C[4]ISRT workload during early operations halting phase. The overall platform C[4]ISRT is represented in terms of continuous workload required to maintain readiness for several warfare areas, depicted here by various colors, as well as total ship systems engineering. Discrete workload events correspond to specific engagements.
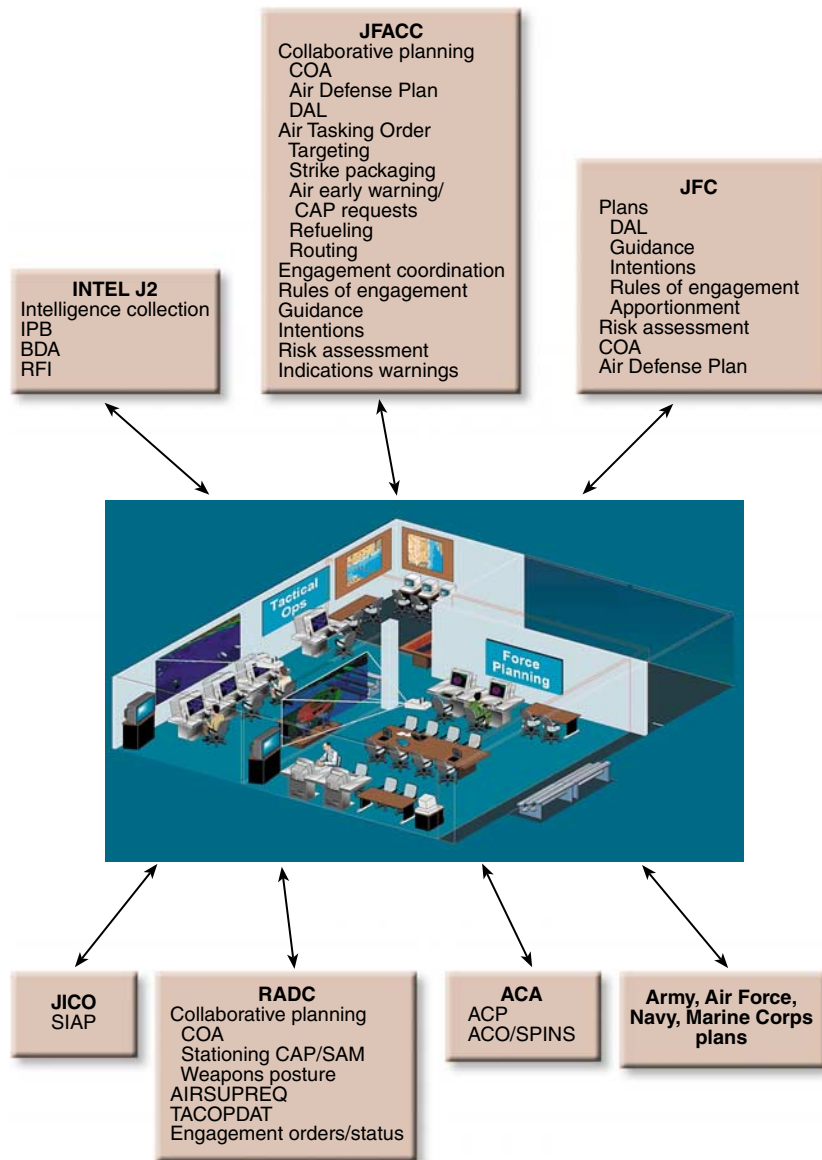
Figure 4. Command elements and information products involved in AADC information exchanges. (ACA = Airspace Control Authority, ACO = Airspace Control Order, ACP = Airspace Control Plan, AIRSUPREQ = air support requests, BDA = battle damage assessment, CAP = close air patrol, COA = courses of action, DAL = defended asset list, INTEL J2 = Intelligence Joint Staff Directorate, IPD = intelligence preparation of the battlefield, JFACC = Joint Force Air Component Commander, JFC = Joint Force Commander, JICO = Joint Interface Control Officer, RADC = Regional Air Defense Commander, RFI = request for information, SAM = surface-to-air missile, SIAP = single integrated air picture, SPINS = special instructions, TACOPDAT = tactical operations data.)

consists of multiple, concurrent planning activities, which include current, future, long-range, and contingency planning sessions. Hence the campaign phase activity of the AADC OPSITs is scripted for multiple days. The OPSITs include external operational plans for other mission areas which may impact the AADC (e.g., strike and close air support competing for combat air patrol aircraft, amphibious landing forces requesting Theater Ballistic Missile Defense for landing zones, etc.). These planning activities introduce a significantly different set of information needs than those required during tactical operations. The AADC Annex describes notional information paths and the external planning systems with which the AADC system must operate (e.g., the Contingency Theater Automated Planning System, Theater Battle Management Core Systems). Finally, projections of future plans for both enemy and friendly forces are critical components and add to the complexity of defining the operational characteristics that appropriately stress AADC planning operations. All of these considerations contributed to the identification of two additional operational characteristics for the AADC Annex: exchange of planning information among command elements and operational tempo.

Defining the planning operational environment required an entirely different approach and presented the AADC Annex designers with a new paradigm, referred to as the planning paradigm (Fig. 5), which is composed of information products, scenario conditions, and timed tasking. The information products (e.g., operation plans and orders, intelligence preparation of the battle space [IPB], Air Tasking Orders, rules of engagement, air control plans, terrain and bathometry data, etc.) are extensive and drive C⁴ISRT connectivity and use.

CVNX: Platform/Battle Group DRM

The 21st Century Tactical Aviation Sea-Based Platform (CVNX) is the planned successor to the

Because the AADC system will support both tactical and planning operations, the AADC OPSITs include both types of operations. Also, during tactical engagements, the AADC can potentially control many different types of platforms. The AADC Annex specifies the tactical engagement activity that addresses AADC real-time tactical alert, warning, and control functions.

In addition to tactical responsibilities, the AADC will be responsible for current and future air defense planning and management. The planning function

External environment and operational characteristics

Required information

Databases (intelligence, MAPS)
Messages
Plans
Orders
Briefs

Scenario component

Enemy/friendly order of battle
Area of responsibility, terrain
Weather, BMC^{4}I
Command structure/
  relationships

Preplanned scheduled events/
dynamic tasking/event schedule

Apportionment changes
Defended asset list changes
Alternate courses of action
Stationing change plans
Force additions/subtractions
Rules of engagement
Engagements
Alerts

Planning process

Output measures of effectiveness

Timeliness
Accuracy of information
Feasibility/compatibility with
  other plans
Interoperability with other
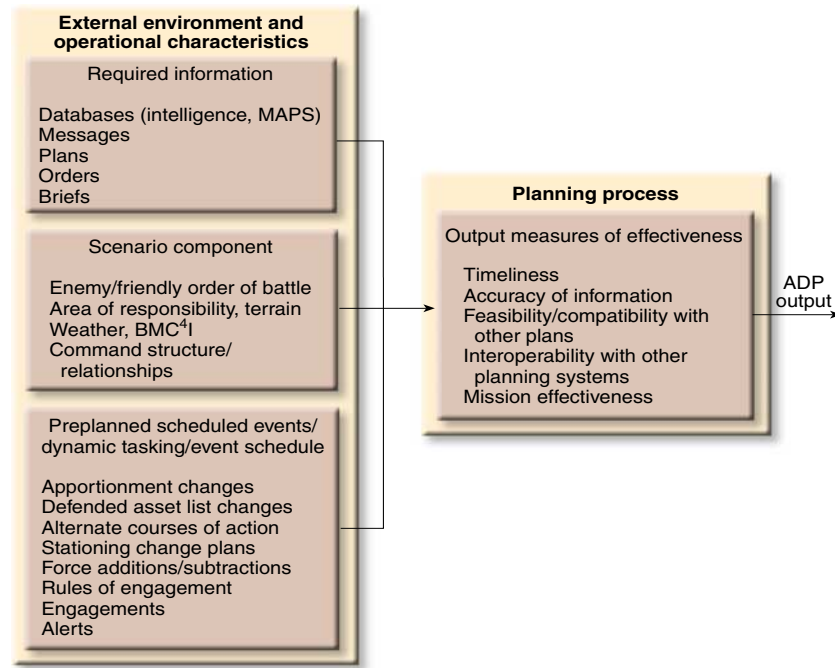 planning systems
Mission effectiveness

ADP
output

Figure 5. AADC planning OPSIT paradigm.

Nimitz-class aircraft carrier. CVNX missions and tasking will span the full spectrum of conflict, from peacetime to major regional conflicts. As the command ship for battle group operations, and (when assigned) for an embarked Joint Force Commander and staff, CVNX will be a hub of information fusion and battle space situational awareness. It will play a significant role in information superiority, exploiting space and electronic warfare systems in order to access and fuse information from all sources.

APL supported the CVNX Program by developing an OPSIT that addressed C^{4}ISRT applications at the battle group level in a Joint force context. As such, the CVNX OPSIT might be considered a subset of a Battle Force DRM. A key challenge of this effort was to modify a scenario that was selected and written to assess CVNX survivability so that it addressed C^{4}ISRT. APL modified the scenario by

- Adding Joint forces to the U.S. order of battle
- Assuming a warning time line so that IPB could be addressed
- Augmenting the threat data so that Information Warfare exploitation and attack could be examined
- Assuming a command structure for both Red and Blue forces
- Crafting engagements that are mission driven

Figure 6 describes the scope of the CVNX OPSIT, from the IPB phase through Red on Blue engagements. The C^{4}ISRT states (A–E) depicted in the figure are purely notional and are meant to be descriptive of analytical efforts. To the far left (not shown) is the

C^{4}ISRT level of effort or state associated with peacetime. The first indication of a possible conflict causes the level of effort to jump from a peacetime level to a prewar level (state A). This is the IPB phase which continues until D-Day, when the level of effort increases dramatically as all mission areas that were preparing for conflict during the IPB phase begin to engage the enemy (state B). This phase encompasses not only Red on Blue attacks (where Blue is defending), but also Blue on Red (where Blue is attacking).

After this initial flurry of activity, for analysis purposes, a lull in engagements is assumed in order to depict a "continuous wartime workload" level for C^{4}ISRT. Although no engagements are taking place per se, all the work associated with evaluating past activity and planning future operations is ongoing. It would then be followed by another flurry of activity comparable to that occurring on D-Day (state D), causing another spike in the C^{4}ISRT level of effort to support this heightened warfighting activity. Over time, this activity may wane as the United States gains superiority in most or all mission areas. Finally, state E depicts a waning workload associated with a cessation of hostilities.

An overarching consideration for all missions is the command structure. As that structure changes, the manner in which the missions are executed may change. For this reason, making the command structure explicit is imperative to the analysis process. The Blue Force command structure was defined and mapped to the OPSIT time line, with special consideration to the locations of commanders. This structure would be critical to establishing the operational environment required to assess coordination and planning activities at the battle group level, similar to what was done in the AADC Annex for a warfare area.

FUTURE CHALLENGES

This article described the methodology employed by DRM developers to appropriately characterize C^{4}ISRT in an operational context. It highlights some of the trends and evolving concepts (e.g., manning reductions, more distributed command structures, support for longer range and precision guided munitions, and the increasing importance of Information Operations) that pose challenges for DRM developers. These
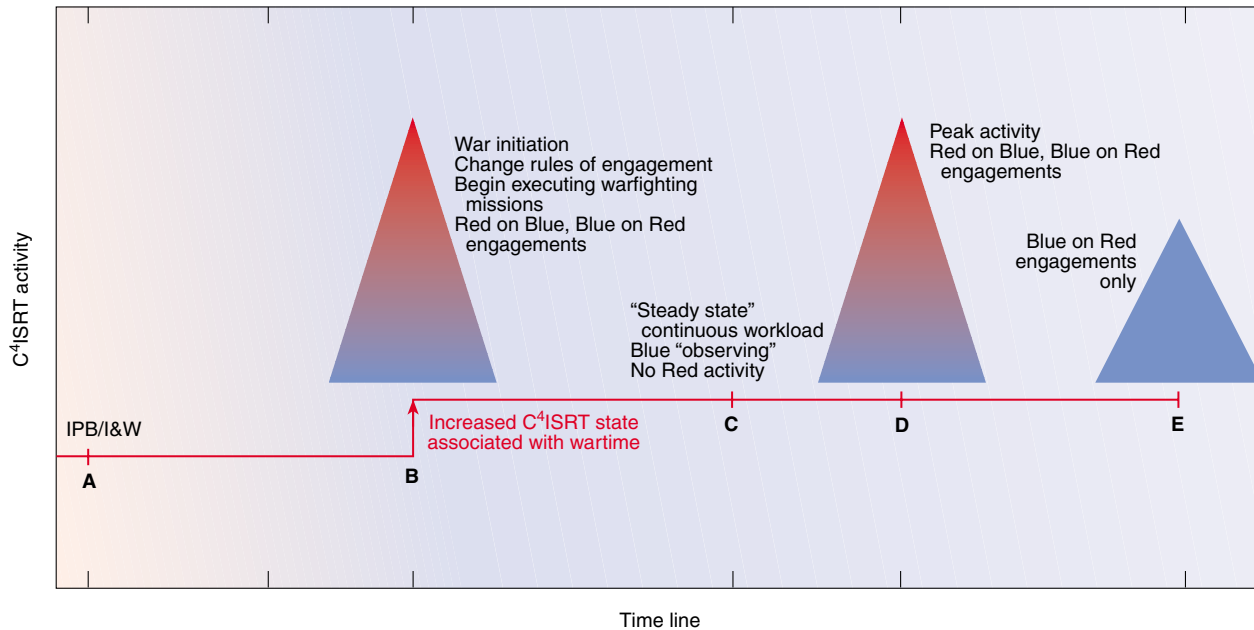
Figure 6. Notional CVNX workload (IPB = intelligence preparation of the battlefield, I&W = indication and warning).

challenges will only increase with the growing emphasis on information superiority as a critical means of enhancing and enabling warfighting effectiveness. DRM developers will need to be knowledgeable about projected system acquisitions, architectural developments, and technology advances. The risk is that invalid predictions have the potential to adversely alter a contractor's design and result in vulnerabilities in warfighting capability. The reward of meeting these challenges successfully, however, will mean the realization of the promise seen on that January morning in 1991.

REFERENCE

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THE AUTHORS

CHRISTINE SALAMACHA received a B.A. from Loyola College of Maryland and an M.S. from The JHU Whiting School of Engineering. Prior to joining the Laboratory, Ms. Salamacha worked for Singer Link as a systems engineer on simulation systems (Army Training Simulation System and Trident II Submarine Simulator). She joined APL in 1983, and worked for 14 years in the Strategic Systems Department evaluating the accuracy of the Trident II Weapons System. She has been with the Joint Warfare Analysis Department since 1997 where she has been focusing her efforts on C⁴ISRT architectures, with an emphasis on Land Attack Warfare. Ms. Salamacha is also involved in developing the APL Food Safety Initiative. Her e-mail address is christine.salamacha@jhuapl.edu.
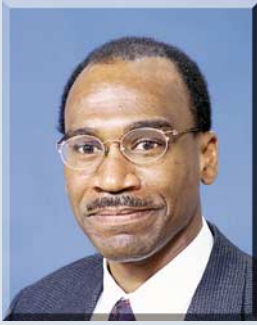
STERLING SMOOT received a B.S.E.E. from the University of Maryland and an M.S.E.E. from George Washington University. Before joining APL he worked as a system engineer for Litton Amecom, Westinghouse, and Northrop Grumman in several areas including radar, Electronic Warfare/electronic countermeasures, IR/EO, and sonar. He has also developed hardware, software, and digital signal processing algorithms for real-time applications. In 1996, Mr. Smoot joined the APL Joint Warfare Analysis Department and has since been focusing his efforts on C^{4}ISRT architectures, examining current capabilities and future trends. His efforts have also included participation in Joint Task Force Exercises and Fleet Battle Experiments, where new concepts are explored at-sea and are enabled by prototype C^{4}ISRT equipment. He was the lead developer of the AADC DRM Annex, and is currently examining applications of C^{4}ISRT to Theater Air Defense and other mission areas. His e-mail address is sterling.smoot@jhuapl.edu.

KATHLEEN FARRIS received a B.A. from Northeastern University and is completing her M.A. at George Washington University in international affairs. She joined APL in 1995, and has been working in the Joint Warfare Analysis Department's Joint Theater Analysis Group. Her e-mail address is kathleen.farris@jhuapl.edu.