The Emerging Joint System of Systems: A Systems Engineering Challenge and Opportunity for APL

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Today, a few influential senior officials envision integrating advanced command, control, computers, communications, and information (C^4I) systems with intelligence, surveillance, and reconnaissance (ISR) systems to provide joint commanders with dominant battlespace awareness. Linking those C^4I and ISR systems into a joint "system of systems" with precision-guided weapons will support warfighting by facilitating precision strikes. The evolving official joint military vision is that the joint system of systems, supported by information warfare, will provide the United States with information superiority and permit the creation of totally new operational concepts to change warfighting. The Applied Physics Laboratory has recognized this view of the future and is positioning itself to participate in engineering the emerging joint system of systems.

INTRODUCTION

From September 1994 until September 1995, APL sponsored the Joint Warfighting Requirements Study to define the challenges, opportunities, and potential tasks for APL in support of the rapidly developing joint approach to military operations.[1,2] The study grew out of a conviction held by the Laboratory's leadership that APL has a responsibility not only to respond to the current systems design and engineering requirements of its sponsors, but also to help those sponsors and others discern their future requirements and to prepare to assist them in meeting those requirements. Thus, the objectives of the study were to

- Gain an understanding of the present meaning and planned development of jointness
- Gain an understanding of how jointness will be implemented at the operational level by joint warfighting, especially with respect to its impact on combat systems development and operation

- Identify the primary areas in which the Laboratory can make meaningful contributions in support of current Navy sponsors and potential new joint sponsors

The study was undertaken by a small group from the Naval Warfare Analysis Department whose efforts were organized and facilitated by the establishment of a study room. This article highlights and updates the key findings and conclusions of the study.

THE EVOLUTION OF JOINTNESS

The changes required by the Goldwater–Nichols Act of 1986 (which reorganized the Department of Defense, placing more authority with the Secretary, the Chairman of the Joint Chiefs of Staff, and the Theater Commanders),[3] the lessons learned from the Persian Gulf War, the demands of the changing world security environment, and especially the domestic requirements

for defense budget reductions have all combined to introduce and promote widespread acceptance of the concept of jointness in the structure, processes, and operations of the armed forces. At the military level, jointness is intended to strengthen the ability of the Chairman of the Joint Chiefs of Staff, the Theater Commanders-in-Chief (CinCs), and their subordinate joint commanders to achieve unity of effort in support of national military objectives through effective coordination, command, and control of assigned subordinate elements of the military services.

The previous Chairman of the Joint Chiefs of Staff, General Colin Powell, became a strong spokesman for the concept and the need for jointness in meeting the new international security challenges with the national resources likely to be available to the armed forces in the future. To further that effort, the Vice Chairman of the Joint Chiefs of Staff, Admiral William Owens, revitalized the Joint Requirements Oversight Council (JROC) and established the Joint Warfighting Capabilities Assessment (JWCA) process to link the warfighting requirements of the joint combatant commanders to the system development and acquisition process of the Department of Defense and the military services. The current Chairman of the Joint Chiefs of Staff, General John Shalikashvili, has continued to lead the movement toward jointness by calling for the introduction of joint warfighting doctrine and encouraging joint training. The development of jointness has now proceeded to the point where joint warfighting is the intended basis for combat operations and joint warfighting requirements are the intended basis for guiding the development and acquisition of the systems by which those operations will be conducted.

THE DEVELOPMENT OF JOINT OPERATIONS TODAY

The national military strategy sets forth two strategic concepts: overseas presence and power projection. This strategy has three components: peacetime engagement, deterrence and conflict prevention, and fight and win. The two strategic concepts are the facilitators of the strategy; the strategy's three components are the tasks to be performed by the joint military. The execution of these tasks is based directly on military capabilities.[4]

Originally, nine military capabilities were established for use in the JWCA process:

- Ground maneuver
- Strike
- Air superiority
- Deterrence and counterproliferation of weapons of mass destruction

- Strategic mobility and its protection
- Command and control/information warfare (C^2/IW)
- Intelligence, surveillance, and reconnaissance (ISR)
- Overseas presence
- Readiness

None of these capabilities is the exclusive domain of any one military service. Indeed, they were selected deliberately to be joint capabilities to which all services could contribute.

Even though all of these capabilities are joint, some must be more integrated—more joint—than others, because they are fundamental to the initiation, conduct, and success of all joint operations. In addition, some must be undertaken earlier in an operation than others.

Overseas presence is a joint capability. All the military services have a role in implementing the strategic concepts of overseas presence and power projection, and all have some capabilities for doing so. The Army, for example, still maintains a significant overseas presence in Korea. In a presentation to the students of the Joint Military Intelligence College, the Chief of Naval Operations cited that presence as the most powerful and persuasive form of overseas presence. He also acknowledged that land-based air power in the region—for example, in Japan to support the land forces in Korea—is the second most powerful and persuasive form of overseas presence. These permanently forward-based forms of overseas presence are often supplemented by forward-based naval forces—for example, the Seventh Fleet in the vicinity of Korea—to provide a powerful, diversified, and truly joint military overseas presence. Together, these overseas presence capabilities are most effective in facilitating the task of deterrence and conflict prevention and the task of fight and win.

In many areas of the world today, however, it is no longer possible to have troops on the ground with land-based air support nearby. Those areas are becoming more volatile as the strategic environment changes. Their number is growing as the U.S. defense budget shrinks. Thus, in many areas of the world, forward-deployed naval forces provide the principal overseas presence, and increasingly they provide it alone. Fortunately, this naval overseas presence capability is most effective in facilitating the tasks of peacetime engagement and of deterrence and conflict prevention in just those areas where such tasks are more likely than ever to be necessary. In such areas, when problems arise, disturbances occur, or crises develop, the naval force on the scene is likely to become the basis upon which a more powerful joint force will be built. The naval commander is likely to become the joint task force (JTF) commander. Thus, while overseas

presence is a joint capability, in many cases it may initially be exercised solely by the Navy and Marine Corps team.

Other capabilities, specifically C^2 and ISR, are more joint, always requiring the integration of capabilities of all the services. Clearly, for joint operations, C^2 is joint by definition and by necessity. To plan and conduct joint operations, all elements of the command structure and the service warfighting elements must be linked.

Until now, the main emphasis has been on building the capability for joint C^2 from the bottom up by assuring jointly interoperable service communications systems and by establishing a common communications and information system, the Global Command and Control System, into which all can feed. Now emphasis is also being placed on developing the capability for joint C^2 from the top down. The Theater CinCs have begun to exercise the command authority given them by the Goldwater–Nichols Act,[3] creating totally joint chains of combatant command over all military service components in the theater. At the outset of most operations today, a JTF is established and given operational control of forces from all services.

In a further development of that concept, the Commission on Roles and Missions (CORM) recommended that "Core Joint Task Force (JTF) elements should be identified and exercised."[5] The Chairman of the Joint Chiefs of Staff concurred, stating that "The geographic CinCs have established predesignated JTF Hqs [Headquarters], and we are taking steps to improve their training."[6] Thus, the U.S. Atlantic Command has already constructed a series of JTF exercises involving elements of all the services (e.g., JTFX-95). Significantly, the JTF commander in most such exercises to date has been a Navy battle group commander.

Like C^2, ISR is an inherently joint capability. Many ISR assets are controlled and directed at the national or theater level, while others are integrated with the tactical forces of the services. Few ISR assets will be under direct command and control at the level of the JTF commander. The commander will be required to combine diffuse ISR assets into a single joint ISR capability for joint operations. Obviously, a joint C^2 capability integrated with the ISR assets is required to accomplish that effort.

As some capabilities are more joint than others, so also some joint capabilities must be implemented earlier in the operational or warfighting continuum than others. Those capabilities are again C^2 and ISR.

When a JTF is established, the first capability required is joint C^2 relationships with the national, theater, lateral, and subordinate commanders. In many cases, the JTF commander will be a Navy commander. In other cases, even if the JTF commander is other than Navy, that commander may be located aboard a Navy ship or the Navy commander may be an immediate superior or subordinate of the JTF commander.

At the same time or just after establishing joint C^2, the JTF commander must begin to combine all available ISR assets into a joint ISR capability to determine the nature of the situation at hand. The operation cannot begin or continue successfully without the results of this effort.

In short, joint overseas presence is a joint capability that naval forces routinely provide in peacetime and that naval commanders are likely to be called upon to expand into joint power projection operations in crisis or wartime. The most joint of capabilities, C^2 and ISR, are also the first joint capabilities that must be implemented when initiating joint operations. Without integrated joint C^2 and ISR capabilities, a joint operation cannot be started, conducted, or successfully concluded. Clearly, then, in the future the Navy will emphasize integrated joint C^2 and ISR capabilities for forward-deployed naval forces for further improvement through the requirements, development, and acquisition process.

Several senior Navy officers who are closely involved in Navy acquisition program development endorsed this view when they visited APL's study room for discussions. The Navy is likely to increasingly establish specific requirements to enhance and integrate the joint C^2 and ISR capabilities of naval forces as the national military strategy continues to be implemented, as joint operations and joint warfighting become the norm, and as the Navy's role of initiator in those operations grows.

JOINT ACQUISITION

In the past, the requirements for joint C^2 and ISR would have been developed by interaction between the Navy staff and the Fleet. Now, however, those who set the requirements, as well as the types of requirements they set, are changing.

By 1995, the JWCA process had completed one full yearly cycle. In that cycle, the plans and programs of the military services and their contributions to joint warfighting were assessed in a joint context. The Theater CinCs were briefed on the results of the assessments and had the opportunity to comment on them. The JROC then integrated the results of the assessments for use as the basis for the Chairman's Program Recommendations, which are sent to the Office of the Secretary of Defense. Those recommendations were used in the development of the Defense Planning Guidance (DPG), which sets the requirements to be addressed by the service programs. Although the JWCA and JROC processes resulted in discussion and generation of all kinds of requirements, Admiral S. R. Arthur, the former Vice Chief of Naval Operations, said that while he was

a member during that period, the JROC spent 60% of its time on C^2/ISR interoperability.

The second yearly cycle of the JWCA process is now well under way. Some of the capability titles have been adjusted to reflect changes in the substance and scope of the material that the assessments must cover. Those joint capabilities are now listed as follows:

- Land and littoral warfare
- Strategic mobility and sustainability
- Sea, air, and space superiority
- Deterrence and counterproliferation of weapons of mass destruction
- Command and control
- Information warfare
- Intelligence, surveillance, and reconnaissance
- Regional engagement and presence
- Joint readiness

Despite the changes, presence, C^2, and ISR remain important joint capabilities.

Indeed, the requirement for C^2/ISR integration is receiving even more attention than in the past. The Nimble Vision joint wargames conducted in October and November 1995 and January 1996 heightened the recognition of the role of integrated C^2/ISR in future joint warfighting and supplemented the JWCA findings with data. Furthermore, the Secretary of Defense has established an integrated product team for C^4I*/ ISR integration and is already taking steps to ensure that C^4I/ISR interoperability issues are addressed in the next DPG.

Once the requirements are established and enunciated in the DPG, current practice is for individual military services to respond by initiating or revising service acquisition programs. In the past, the degree to which they responded could be enforced only by the Office of the Secretary of Defense. That enforcement usually was based only on programmatic, not military, considerations. Now, in the cycle of the JWCA process, the completed service programs are assessed again in the spring and comments in the Chairman's Program Assessment are forwarded to the Office of the Secretary of Defense. This process gives the Joint Staff another opportunity to emphasize joint military requirements that may have been overlooked or underemphasized by the services. On the basis of this assessment, the Secretary of Defense can take corrective action in the Program Decision Memoranda that approve or revise the service programs.

There are now plans to further strengthen the joint influence over service C^4I and ISR programs. The Joint Staff has established a Joint C^4I/ISR Battle Center to provide analysis, modeling, and simulation in support of C^4I/ISR requirements determination. Furthermore, a C^4I/ISR Decision Support Center is being established to provide acquisition decision support, including cost–benefit analysis.

The military services still control the funding and specific developmental decisions, however, and they may choose not to make jointness the first priority of system development. It is becoming clear that such service independence in the development and acquisition process may soon change.

More and more joint programs are being established, but no uniform chain of command has been established through which the managers of those programs report to acquisition executives. In some cases, where one service is the Executive Agent for a program, the Service Acquisition Executive is also the Joint Acquisition Executive. In other cases, such as the Joint Strike Fighter program, the Joint Acquisition Executive rotates between services as program managers change. In still other cases, such as theater missile defense, the Ballistic Missile Defense Organization is fulfilling at least some of the roles of Joint Acquisition Executive. When the DoD Space Architect was established, determining who would become the Joint Acquisition Executive was a major and contentious decision.

A number of recommendations have been made, including one by an Office of the Secretary of Defense process action team and another by the Defense Systems Management College, for the establishment of a formal Joint Acquisition Executive structure that will be consistent across the DoD. If implemented, such a move would take from the services some of their money and their independence in developing and managing acquisition programs. Momentum to reform and centralize the entire DoD acquisition process is growing. The most notable example is the recently introduced Roth–Kasich bill, which would create a Defense (or effectively joint) Acquisition Agency that would subsume current service acquisition functions.

VISIONS OF FUTURE JOINT WARFIGHTING

Today, the emphasis in the requirements and acquisition process continues to be on improving and integrating C^2 and ISR capabilities to support joint warfighting. Nevertheless, the Joint Staff has already created a vision for joint warfighting of the future that relies heavily on advanced and highly integrated C^2 and ISR capabilities.

Admiral William Owens, Vice Chairman of the Joint Chiefs of Staff, and Vice Admiral Arthur

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* Although C^2 has been identified as a joint warfighting capability, two other terms also are used to describe the systems that provide command and control capability: command, control, communications, and intelligence (C^3I) and command, control, communications, computers, and intelligence or information (C^4I). Frequently, the three terms are used interchangeably. This article uses the term used by the organization or reference being cited.

Cebrowski, Director of Command and Control, Communications, and Computer Systems (J6), have stimulated and led development of that conception of future joint warfighting. They articulated a vision that called for providing the joint commander with dominant battlespace awareness over an area 200 × 200 square miles on the basis of fully integrated C^2 and seamless, robust ISR. They envisioned supporting warfighting by the use of precision weapons with sensor-to-weapon connectivity (Fig. 1).

In describing this vision in more detail, Admiral Owens wrote that the flagship pronouncements of the services—including the Navy's *Forward . . . From the Sea*[7]—are remarkably similar in their vision of the future.[8] He pointed out that each relies on three areas of technology—advanced C^4I, ISR, and precision-guided munitions (PGM). Admiral Owens believes that C^4I, ISR, and PGM systems, taken together, constitute qualitatively a quite different military potential than exists today. The interactions and synergism of those systems constitute something new and very important: a new system of systems. That system of systems is fundamentally a joint military entity. Admiral Owens is convinced that, as this broad concept emerges over the next decade, it will create a revolution in military affairs and a new appreciation of joint military operations. If the United States decides to accelerate

the process by emphasizing those systems and weapons that drive the revolution, he believes that we will reach our goals years—perhaps decades—before any other nation. That will be the factor on which we base our future military superiority.[8]

In remarks to the U.S. Naval Institute/Armed Forces Communication and Electronics Association Symposium at Monterey, California, in January 1995, Paul Kaminski, the Under Secretary of Defense for Acquisition and Technology, expressed the additional need for the development of improved sensors with target recognition and discrimination capabilities as well as the creation of a facility to fuse sensor information and make it available by "pull" to the shooters. Others, in industry, believe common standards are needed.

Another need, and probably the most difficult part of implementing this vision, is the need for a cultural change in the military services concerning the ownership of sensors and shooters and concerning the level at which tasking and prioritization of sensor coverage and direction of fire occur. Yet, the vision is being driven by fiscal and strategic necessity as well as by confidence in the rapid advancement of information technology. Because it is both necessary at the practical level and alluring at the conceptual level, there is strong impetus to implement the vision now.
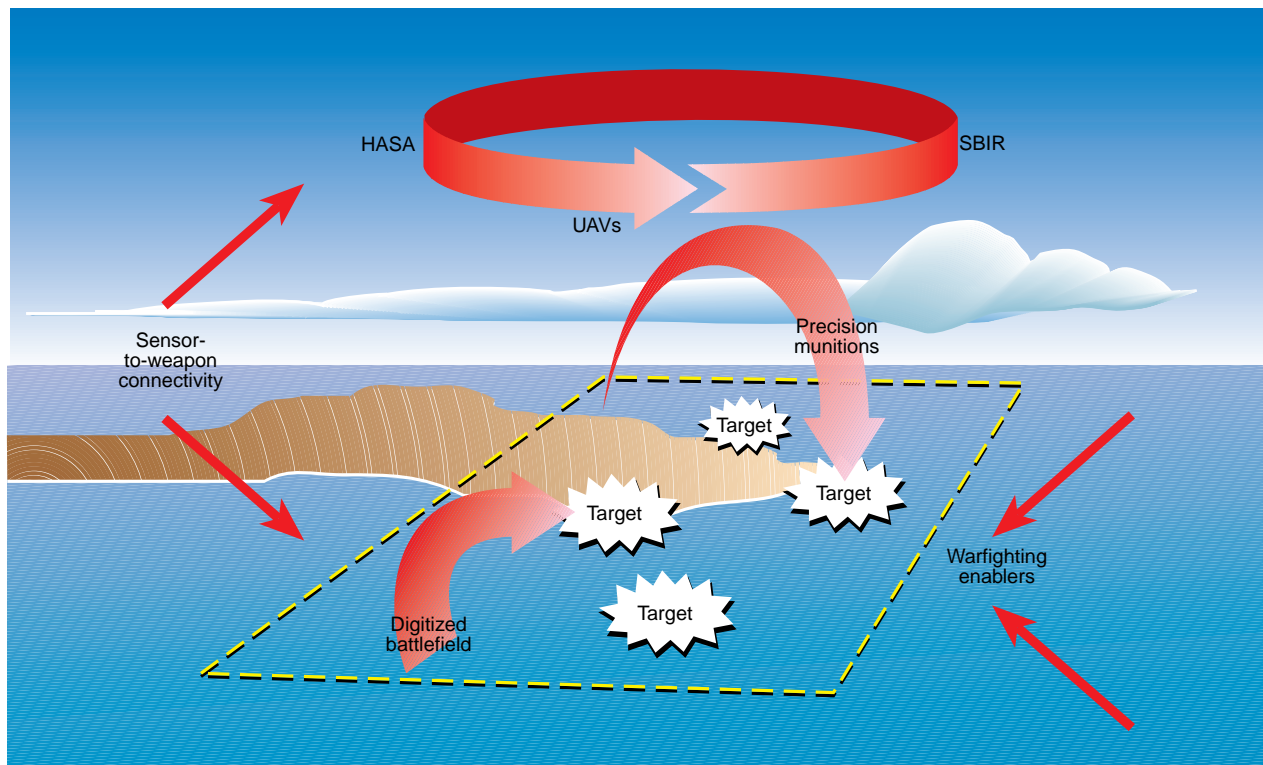

Figure 1. A system of systems to provide dominant battlespace awareness and support warfighting by precision strikes. (HASA is high-altitude satellite architecture, SBIR is space-based infrared, and UAVs are unmanned aerial vehicles.)

Those on the Joint Staff responsible for charting the path from today to joint warfighting of the future have already moved beyond the initial vision of their leaders. They have undertaken the preparation of *Joint Vision 2010*, which encompasses the entire range of joint warfighting.[9] During a year of work, involving many drafts and coordination with the services and the CinCs, that document underwent considerable revision. Nevertheless, the original concept of dominant battlespace awareness and a C^4I/ISR system of systems was retained as a key factor in future warfare. Furthermore, the concept of information superiority has been emphasized.

Joint Vision 2010 begins by anticipating continuity in American goals and interests and continuity in the missions, tasks, and strategic concepts of the armed forces to 2010. Peacekeeping, deterrence and conflict prevention, and fight and win will continue to define the broad strategic requirements for the military. Peacetime presence and power projection will remain the fundamental strategic concepts of the future force. The document anticipates that this will also be an era of accelerating technological change. It asserts that improvements in information and systems integration technology will significantly impact future military operations.

Information technology will improve the ability to see, prioritize, assign, and assess information. Also, the integration of sensors, platforms, and command organizations, along with advances in computer processing, precise global positioning, and telecommunications, will provide the capability for determining accurate locations of friendly and enemy forces and for collecting, processing, and distributing relevant data to thousands of locations. Harnessing the capabilities potentially available from this system of systems can provide dominant battlespace awareness. But to maintain an edge over an adversary, the United States must have not only the capability to collect, process, and disseminate an uninterrupted flow of information—the joint C^4I/ISR system of systems—but also the capability to exploit the adversary's ability to do the same.

Those capabilities will require supporting the C^4I/ISR system of systems by both offensive and defensive information warfare (IW). Offensive IW will degrade or exploit an adversary's collection or use of information. It includes both traditional methods, such as a precision attack to destroy an enemy's command and control capability, and nontraditional methods, such as electronic intrusion into an information or control network to convince, confuse, or deceive enemy decision makers. Defensive IW will be required to protect our ability to conduct information-intensive operations. It can involve traditional methods, such as physical security and encryption, and nontraditional methods, such as antivirus protection.

The document outlining this vision maintains that the combination of the $C^4I/ISR/PGM$ system of systems with offensive and defensive IW can provide the United States with information superiority and will change how we conduct operations by 2010. Information superiority will enable the traditional functions of maneuver, strike, protection, and logistics to be reformulated so that they become, in effect, new operational concepts: dominant maneuver, precision engagement, full dimensional protection, and focused logistics. Taken together, those four new concepts will allow the United States to dominate the battlespace (Fig. 2). Describing each of these new operational concepts, the joint vision highlights the critical nature of information in their implementation. Discussing full-spectrum dominance, it again emphasizes the importance of information superiority, surveillance, and reconnaissance.

At this time, the foregoing is simply guidance for the future development of joint capabilities and systems. Indeed, many people, including several Theater CinCs, do not fully share the vision. Furthermore, for some parts of the vision—for example, the parts concerning IW—no agreed-upon definition or clear policy yet exists. Nevertheless, the momentum is apparent; an integrated C^2/ISR capability based on a system of systems, supported by offensive and defensive IW to assure information superiority, will be the basis for joint operations and joint warfighting of the future.

IMPLEMENTING THE VISION

The vision of future operations and warfighting just described has already begun to be implemented in naval operations. During Operation Sharp Guard, naval forces operated off the coast of the former Yugoslavia for months, continually exercising joint C^2 and ISR capabilities. On only a few occasions were weapons systems employed, but when they were, they were employed in precision strikes directed and supported by joint C^4I and ISR systems. Furthermore, those strikes were conducted primarily for offensive IW purposes—to deny Bosnian Serb leaders effective C^2 of their forces and to pressure them to come to the bargaining table.

Such operations suggest the changing nature of warfighting. In the past, the key to successful warfighting was the best use of weapons. The principal requirement was to find and destroy the enemy's forces. The engaged commander usually targeted the weapon. Sensors supported weapons and were usually integral to them. In the future, the key to successful joint operations often will be the best use of information. The main requirement may be to gain, deny, or convey information. Weapons may be used to support the optimum use of sensors and to conduct offensive IW. When used, weapons may be targeted by the best-informed commander and supported by sensors that are

Figure 2. The *Joint Vision 2010* anticipates that the C⁴I/ISR/PGM system of systems, combined with offensive and defensive IW, will provide the United States with information superiority and enable the development and implementation of new operational concepts.

not part of the weapon or force. Slowly but surely, the relationship of weapons and sensors is already changing. With that changing relationship, the priority of C^4I and ISR system requirements to weapons system requirements is changing.

The Chairman of the Joint Chiefs of Staff intends the *Joint Vision 2010* to be implemented. In responding to the CORM recommendation that a vision must drive joint requirements, the Chairman described the main elements of the joint vision, made it clear that he supports it, and has taken steps to ensure that it is integrated into operations throughout the armed forces.[10] In the current draft of his Triennial Report on Roles and Missions he stated, "To give our forces speed, lethality, and potency, we must lead in the ability to tie intelligence–surveillance–reconnaissance architectures to an advanced command and control structure."[11] Since then, the Chairman has directed that a joint warfighting concept be developed to spell out how

the vision will be implemented. This concept is likely to build on and sustain the momentum created by the vision.[12] Likewise, in his response to the CORM findings, the Secretary of Defense highlighted the *Joint Vision 2010* and coupled it with the statement that "the Joint Staff will accelerate its efforts to create an integrated C^4I architecture."[13]

IMPLICATIONS FOR THE FUTURE

The movement toward jointness is continuing to gather momentum, and the operational level is now being emphasized. The commitment to joint operations and joint warfighting requires that all forces be capable of operating in a joint environment. Today, naval forces are increasingly facing the need to establish joint C^2 and initiate joint ISR. That need will create new requirements for improving existing naval C^2 and ISR capabilities by upgrading naval C^4I systems

and upgrading their links to the C^{4}I systems of the other services and to a variety of ISR nodes.

Enunciating the vision of integrating current advanced C^{4}I and ISR systems to provide dominant battlespace awareness and linking them with PGMs to facilitate precision strike was the first step in developing a joint system of systems. This vision has now been expanded to encompass the view that advancing technology will permit the creation of a C^{4}I/ISR system of systems that, when supported by IW, will provide information superiority. This superiority is expected to permit the development of new and more powerful operational concepts that will form the basis for all operational warfighting. Once the vision of an integrated C^{4}I/ISR system of systems, supported by IW and forming the basis for all joint warfighting, has been more fully developed and explicated, it will create many joint requirements for future joint C^{4}I, ISR, and IW systems. As information increasingly becomes the basis for the vision of future joint warfighting, those C^{4}I, ISR, and IW requirements are likely to be viewed as the most important of all joint warfighting requirements.

The process of transforming the vision of future joint warfighting into requirements and guidance for the development of tomorrow's C^{4}I, ISR, and IW systems has only just begun. It is not yet sufficiently defined, organized, or sponsored to form a primary area of work for the Laboratory. Nevertheless, it is already apparent that C^{4}I, ISR, and IW will become a major focus of requirements, development, and acquisition in the future.

That shift in focus will assure that there is much future work to be done by APL. Initially, the requirements, development, and acquisition process will stress introducing greater interoperability between all service C^{4}I and ISR systems and creating high-leverage C^{4}I/ISR linkages to existing precision-guided weapons systems. Thus, efforts will be required to assure the compatibility and integration of current APL activities and systems with joint C^{4}I, ISR, and IW requirements and systems. The necessity for C^{4}I interoperability and ISR sensor-to-weapon linkage will influence ongoing design and developmental work in the areas of air and missile defense and strike warfare. For example, requirements may be established for APL to extend the Navy's Cooperative Engagement Capability to include other military services and joint systems. Likewise, Navy Tomahawk mission planning systems may have to be linked and interoperable with systems of other services and with joint strike mission planning systems.

Later, however, joint requirements will be met increasingly by the development of new joint systems, creating a demand for the wide range of capabilities and talents at APL. The development of joint C^{4}I, ISR, and IW systems will require the analysis of joint requirements and the conceptualization of interoperable joint architectures; the conduct of basic research and scientific and technical investigations in a wide variety of information age disciplines; C^2, ISR, and IW system design and prototype development; conduct of critical experiments; and finally, system and network engineering. Those efforts eventually may be undertaken for a joint program manager functioning within a centralized DoD or joint development and acquisition process.

THE APL RESPONSE

The leadership of APL has recognized the challenge that joint C^{4}I, ISR, and IW technology development and systems engineering will pose for the Laboratory's ability to continue to support the Navy; its research, development, test, and evaluation community; and others. In this context, we have taken the opportunity to commence strategic planning at its best: early recognition of the prospective future and preparations to respond to that future when it arrives. The information that formed the basis of APL's Joint Warfighting Requirements Study[1,2] is updated regularly and it will be made available electronically throughout the Laboratory. Initiatives are under way to identify APL's current expertise and capabilities in the areas of C^{4}I, ISR, and IW and to determine the need for other personnel and for relationships with other organizations that can augment them. New business development has created a "thrust area" for C^{4}I, and contact has been expanded with the organizations that will ultimately support and sponsor C^{4}I, ISR, and IW system development. These efforts will assure that in the future the Laboratory is prepared to participate as a partner in engineering the joint system of systems, contributing its unique capabilities in the design, engineering, testing, and transition of systems to the Fleet.

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