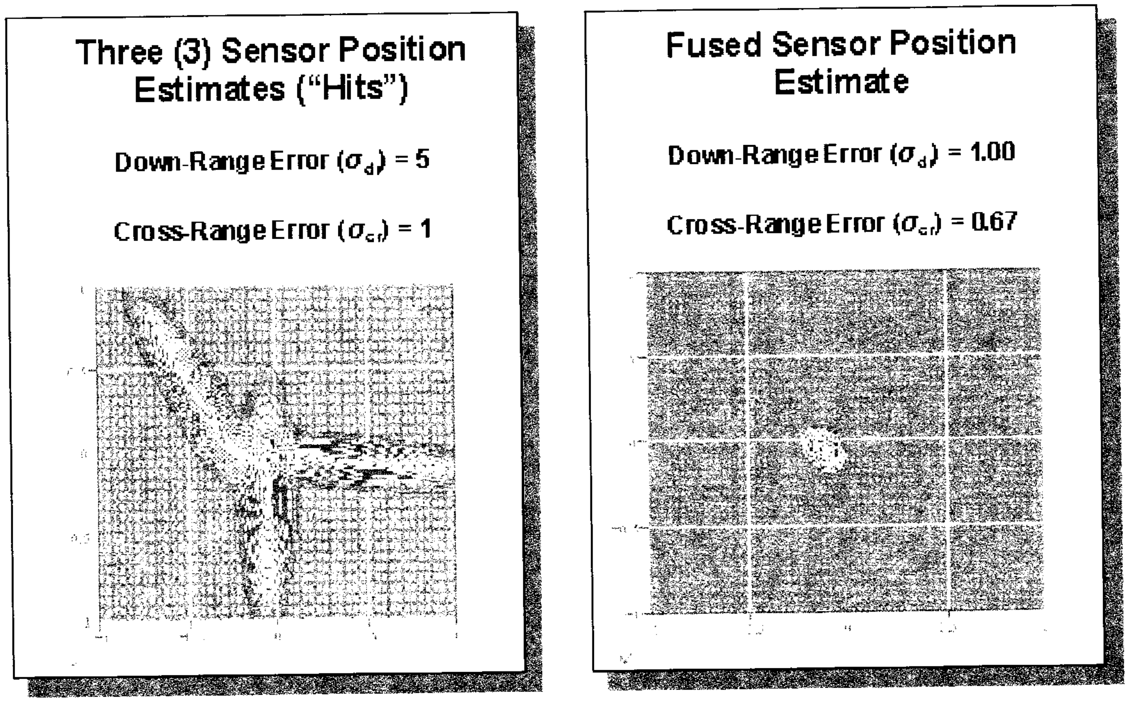


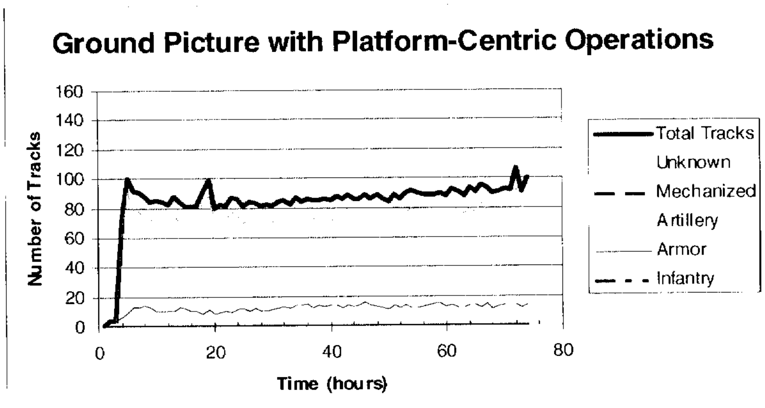
Figure 27. Payoff of Sensor Fusion

(AWE) in January 1997, and in Information Superiority Experiment (ISX) 1.1 in September 1998.

An example of the performance improvement of a sensor network against moving ground targets vs. a stand-alone sensor is portrayed in Figure 28, Performance Increase of Sensor Network Against Moving Ground Targets.[74] This figure highlights the degree to which the capability of a force to track and identify moving targets can be improved through the employment of a sensor network employing multiple types of sensors. In some cases, the capability to replay and review information that has been collected by sensors can have a significant operational payoff. This was the case during *Operation Desert Shield/ Desert Storm*, when information collected by the E-8 JSTARS was replayed and analyzed to locate forward operating bases that were being used by Iraqi forces.

Operational Capabilities of Mission Specific Sensor Networks

Sensor networks provide the warfighting force with the operational capability to synchronize battlespace awareness with military operations. In some mission areas, such as the Joint Suppression of Enemy Air Defenses and Joint Theater Air and Missile Defense, the capability to generate a very high level of battlespace awareness can have significant operational value. Consequently, commanders place a high value on generating this awareness. Mission-specific sensor networks provide commanders with the capability to task organize a broad spectrum of sensing capabilities to support the prosecution of the JSEAD and Air and Missile Defense missions. For



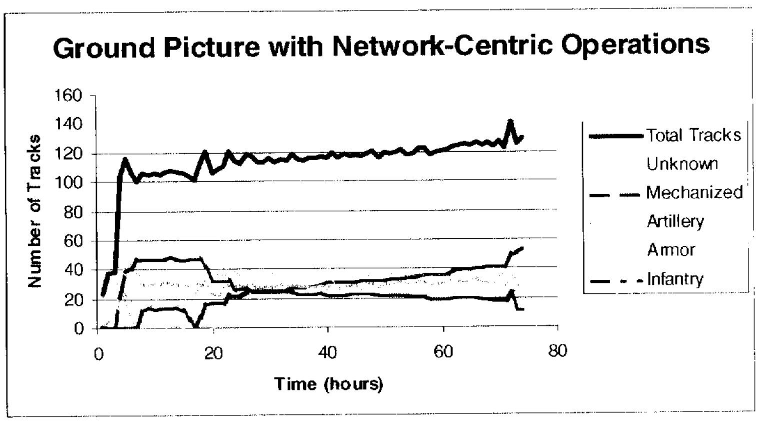


Figure 28. Performance Increase of Sensor Network Against Moving Ground Targets

example, in supporting the prosecution of the JSEAD mission, a sensor network commander can employ space-, air-, and ground-based sensors to locate elements of an Enemy Air Defense System. Space-based sensors include missile detection satellites, such as DSP or SBIRS, as well as space-based SIGINT systems. Air-based sensors can include the E-8 JSTARS, the U-2, and the multiple types of UAVs. Ground-based sensors can include unattended ground systems, as well as special operations forces.[75] To effectively employ this broad range of sensors and to maximize their performance in support of the JSEAD mission, a sensor network commander needs to have the operational capability to maneuver, task, and prioritize the employment of sensors. This includes the capability to maneuver sensors, such as UAVs and JSTARS, to specific locations in the battlespace, as well as the capability to task sensor payloads in near real time. In some cases, this may require the ability to retask in real time a space-based sensor with a preplanned mission to collect information in support of battle damage assessment. Furthermore, real-time sensor data fusion requires that the information collected by these sensors be transported with near-zero time delay (a very high velocity of information) to high-performance data fusion nodes. Maintaining a high velocity of information between the elements of sensor network places a demand on the infostructure for dynamically prioritizing the transport and processing of information (Quality of Service).

In closing, we can see that the ability to significantly increase battlespace awareness and knowledge corresponds to a new core competency, a competency that is fundamental to achieving information superiority. As has been discussed in this chapter, developing this new core competency calls for new operational capabilities, such as the capability to deploy and operate sensor networks to ensure critical information availability. New concepts for network-centric operations, which integrate changes in technology, organization, and doctrine, are examples of new network-centric mission capability packages, a concept that will be discussed in detail in future chapters.

Command and Control and Execution

We have seen in the previous chapter how adopting NCW significantly increases our ability to generate shared battlespace awareness and to contribute to battlespace knowledge. In this chapter we address the implications of NCW for command and control and execution.

The very essence of command and control (C2) lies in the ability of a commander, at any level, to make the most out of the situation. In order to do so, commanders come equipped with the education, training, and experience that they bring to the situation, the assets and supplies they are assigned, and with access to information and decision support.

The output of a C2 process consists of the decisions a commander makes, the degree to which the commander's perception of the situation and the commander's intent is shared among the forces, and manifestations of command decisions (e.g., plans, orders, and information). In the final analysis, none of these C2 products will make any difference unless they are translated into effective actions in the battlespace. This is one reason this chapter addresses both C2 and execution. Another reason is the C2 and execution processes are, as a result of a shift towards network-centric operations, beginning to merge into a single, integrated process. This is driven by a need for an increased pace of operations and the need to improve responses in time-critical situations. Using network-centric concepts and enabling technologies, we can achieve a very high degree of coupling between C2 and fire control. This tight coupling enables us to translate high levels of shared battlespace awareness into increased combat power. Increased combat power can also be achieved in a number of other ways. These include collaborative planning and execution, reach back and split operations, and self-synchronized operations. Examples of these are presented later in this chapter.

NCW provides opportunities to improve both C2 and execution at each echelon in the context of particular missions and tasks. These opportunities will come about because:

1) decision entities or C2 elements will be more knowledgeable;
2) actor entities will be more knowledgeable;
3) actor and decision entities will be better connected;
4) sensor entities will be more responsive; and
5) the footprint of all entities will be much smaller.

Each of these improvements makes it possible for us to do things differently. It is important to stress that these properties of NCW offer opportunities to better match our approach to each set of battlespace circumstances and conditions to achieve greater levels of both effectiveness and efficiency.

Decision entities that are more knowledgeable will be able to approach problems in ways that less knowledgeable entities cannot. Decision-making processes no longer need focus on the defensive oriented approaches that were required to hedge against uncertainties (fog and friction). They can now focus instead on being proactive and agile. Increased levels of battlespace knowledge mean that we can accurately bound our adversary's capabilities. This allows us to devote more attention to shaping the battlespace and less to reacting to sudden or unexpected changes. Less energy will be spent on planning. The C2 and execution processes will become integrated as energies are devoted to contingency execution monitoring and real-time modification.

Knowledgeable actor entities will alter the approach to C2 from a process that embeds plans and decisions (making them detailed) to a process of conveying broad intent and orchestrating support of executing entities. With less detail being incorporated into orders, the speed of command can be greatly increased. The mechanics of C2 will be significantly reduced as the need to embed information in commands is reduced, contributing to increased command agility.

Better connectivity among actor and decision entities will result in an increased ability to react and effectively respond to changes in the situation. This agility will be greatly enhanced by having more responsive sensor entities. The ability to rapidly respond to changing circumstances has profound implications for C2 and related planning activities. It makes planning significantly easier as plans neither need to last as long, nor do they need to account for as many factors.

The ability to fine-tune operations will tend to make planning a continuous process that merges, under certain circumstances, with execution to the point where planning no longer remains a separate activity.

At any given level these changes will radically alter the nature of C2 by allowing us to push down more responsibility to what are now lower levels in the organization. Despite the resulting increased operating tempo, high-level decision entities will find themselves with more time and resources that can be concentrated on monitoring the situation and looking ahead to ensure that problems are identified and resolved as quickly as possible, perhaps even before the actor entities realize they exist.

NCW offers the opportunity not only to be able to develop and execute highly synchronized operations, but also to explore C2 approaches based upon horizontal coordination, or self-synchronization, of actor entities. In fact, the Marines have adopted *Command and Coordination* as their preferred term for command and control in future operations.[76]

This adds a whole new dimension to command and control. It recognizes that the behavior of an organization can be influenced and perhaps even controlled without the issuance of detailed top-down direction. It offers the alternative of achieving the desired results in another way. That is to say that organizational behavior could be consciously designed to be an emergent property that derives from the commander's intent, as internalized by actor entities, the degree of battlespace knowledge available and the ability of decision entities to minimize the constraints imposed on actor entities by virtue of the resources allocated to actor entities. It is hard to overestimate the impact that this new dimension of command and control will have on the way we will approach operations in the future.

The future battlespace, whether it involves large-scale, theater-size operations or situations in an urban environment, will be fast-paced and complex. It has always been the job of command and control to deal with the complexity of battle. NCW gives us important new tools to deal with this complexity. Until recently, it has been almost a fundamental article of faith that as we got more advanced technologically and organizationally, we would be able to tame complexity by insightful decomposition and massive amounts of processing power. We believed that if we could understand the underlying processes, we could handle any level of complexity by hard work and rigorous analysis, and with enough time and intellectual energy, we could develop the necessary levels of understanding to be successful.

There are scientists in many fields who are now expressing doubt about our traditional approach to very complex problems. They point out that many relatively simple processes cannot be adequately modeled, even with the vastly increased computer power we have recently developed.[77] They point out that system behaviors can become unpredictably unstable or chaotic.[78] Managing complex systems and situations in the absence of reliable predictive models is, of course, what command and control has always been about. NCW gives us more to work with to tame complexity and bound aberrant system behavior.

Exciting work is being done by the Marine Corps in their Combat Development Command to explore the characteristics and limits of emergent behaviors that result from various small unit/group rules of engagement and information environments.

NCW gives us the opportunity to explore the vast middle ground between the Industrial Age top-down hierarchical command and control approach and the highly decentralized model of small units assigned pieces of the problem with only their organic capabilities. This vast middle allows us to consider a host of command and control approaches, many of which could be used simultaneously in the battlespace of the future, each optimized for a specific task or function. The overall design of command and control, the way each mission, function, and task will be managed, needs to be conceived in such a way as to bound the overall behavior of the forces. In other words, the goal of command and control—to achieve high levels of force effectiveness and efficiency—needs to be achieved within acceptable levels of risk.

There are different kinds of risk that need to be considered. Added to the risks that commanders have dealt with for centuries are the risks of non-linear effects that come with the increased complexity of the battlespace of the future. A non-linear effect is one that is grossly disproportionate to the change in the independent variable(s). If an organization or system is behaving in a well-mannered or linear fashion, a small change in conditions (inputs or independent variables) will result in a small change in the result (output or dependent variable). A non-linear system or a system with discontinuities will exhibit large changes in behavior given small changes in initial conditions.

To the extent we currently understand the conditions under which this happens in battle, a different set of conditions is what we'll experience in the future. In large part our current approach to command and control is designed to reduce the chances that we will fall victim to these non-linear effects. Our current approach to C2 is designed to minimize mistakes and place bandages on potential weaknesses. However, this approach does not translate well into the Information Age, for it is based on limited information flows and restricted initiative, and is an approach that requires (or at least desires) overwhelming force. At times we have adapted approaches that have reduced operating tempo to achieve this objective. Our command and control challenge is to eliminate (or significantly reduce) the risks that accompany non-linear behavior or, if possible, put ourselves in a position to exploit the anomalies in an environment where the operating tempo, information flow, and initiative are increased.

Speed of Command

A basic measure of one's command and control approach, organization, and systems is speed of command, or the time it takes to recognize and understand a situation (or change in the situation), identify and assess options, select an appropriate course of action, and translate it into actionable orders. As long as the appropriate course of action is within the framework of the current plan, the plan survives. Replanning is a time consuming and manpower intensive activity during which combat effectiveness is, by definition, not what it could be. Recognizing that there is a problem or opportunity is the first step in this process.

In platform-centric military operations, situational awareness steadily deteriorates. Periodically, it is reestablished, and then it deteriorates again. Consequently, one reason no plan survives initial contact with the enemy is because situational awareness doesn't. Low levels of awareness slow down the planning process, as commanders delay decisions until key elements of information are updated.

The effect that network-centric operations can have on the speed of command was illustrated during the Taiwan Straits crisis in 1995, when the People's Republic of China attempted to influence Taiwanese elections with some highly visible saber rattling. This potentially explosive situation was defused when the United States quickly maneuvered two carrier battle groups into the Taiwan Straits. For our purposes, the most exciting part of that story was the fundamentally different way that command and control was exercised. The nature of Admiralty changed when then Vice Admiral Clemins, as Commander, Seventh Fleet, and his subordinates reduced their planning timelines from days to hours. This magnitude of change suggests that something very fundamental changed.

Admiral Clemins was able to use e-mail, a very rich graphic environment, and video teleconferencing to create and maintain a high level of shared awareness, and use this shared awareness to plan collaboratively. This significantly accelerated the process of synchronizing the operations of two carrier battle groups.[79]

At the tactical level, the U.S. Navy's *Fleet Battle Experiment Series* has demonstrated that combat power can be significantly increased through the ability of tactical units to self-synchronize operations based on a shared combat operational picture and shared knowledge of commander's intent. The self-synchronization that occurred was enabled through employment of a land-sea engagement network.

At what we currently refer to as the operational level of war, emerging Joint and Service doctrine and future warfighting concepts address the imperative for accelerating the pace of movement of forces, maintaining an unrelenting operational tempo, and decisively engaging the enemy and impacting events at the time and place of our choosing.[80] The emerging warfighting calculus asserts the potential of shock and awe to dislocate and confuse an enemy to the point that his warfighting structures quickly disintegrate and his feasible courses of action are rapidly reduced. The anticipated result is an unequivocal military decision with minimum cost to both sides.

Closely associated with these ideas is the concept of strategic lockout. Lockout refers to the situation that exists when an adversary's strategic objectives have been locked out because he has no remaining viable courses of action. This relationship is portrayed in Figure 29. Although the hypothesis is still unproven, the underlying logic is that focusing on strategic lockout can play a key role to enable a warfighting force to achieve a rapid termination of hostilities.

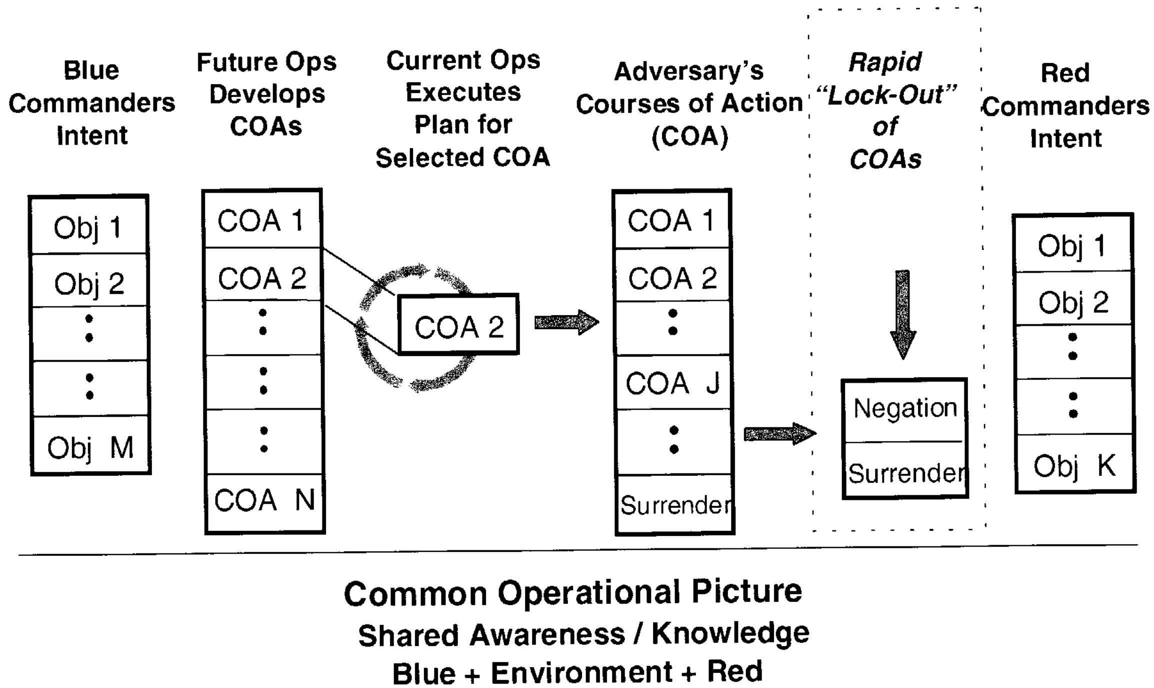


Figure 29. Lockout

Rehearsal

High fidelity rehearsals can achieve significant increases in combat effectiveness. By exploiting the infostructure that enables network-centric operations, warfighters can access sophisticated mission planning tools and simulators. Given the ability to repeatedly rehearse and analyze a given mission with the latest information available, a warfighter can improve the plan, develop enhanced awareness, and as a result, increase the probability of a successful outcome.

Engagement with Enhanced Awareness

Currently, computer-based software applications (e.g., Air Force Mission Support System (AFMSS), PowerScene, and TopScene) enable warfighters to generate an enhanced awareness of the battlespace by first planning and then rehearsing missions through photo-realistic visualization of a battlespace using 3-D scene visualization (virtual reality).

For example, a pilot can rehearse a mission several times and generate an increased awareness of the ingress route, engagement zone, and egress route. Threat characteristics, such as radar detection zones and surface-to-air missile (SAM) engagement zones can be represented in 3-D, enabling a pilot to plan and rehearse missions that minimize the probability of detection and engagement by enemy air defense systems. This increased awareness increases survivability by enabling a pilot to select a route that exploits terrain masking and or presents a reduced signature to known air defense radars. Furthermore, mission rehearsal can enable a pilot to increase the probability of target acquisition by identifying an attack profile that maximizes target acquisition under various light or weather conditions. Mission rehearsal can also help a pilot identify situations where mission planners have provided potentially incorrect target coordinates.

Each of these examples was played out in *Operation Deliberate Force* in Bosnia (August-September 1995) when NATO aircrews flew 3,515 sorties of which over 60 percent were flown by shooters. The value of enhanced battlespace awareness was manifested in the form of increased precision and lethality, reduced collateral damage, and minimal losses. Aircrews successfully attacked over 97 percent of the targets and destroyed or inflicted serious damage on more than 80 percent of them. The target set, which consisted of over 338 aim points within 48 complexes, was painstakingly selected, checked, and rechecked to virtually eliminate the risk to civilian life and property. During the entire operation, only a single aircraft, a French Mirage 2000K, was shot down. The crew survived and was eventually repatriated.[81] The value that emerged as a result of precision engagement was clearly a function of timely and accurate information, such as information on the status and disposition of adversary forces, as well as detailed environmental information.

Execution

We have seen how employing NCW provides us an opportunity to increase battlespace awareness and knowledge, to develop new approaches to command and control, and to more dynamically plan and rehearse missions. In the final analysis, this will not make much difference if we cannot translate these improvements into more effective and efficient execution.

Actor entities will have greatly increased access to information and expertise as was explained earlier in the example from the *Power of NCW* section. In addition, actor entities will be better able to communicate with all other battlespace entities. This is not of itself necessarily good, but if we do it right, an actor's increased knowledge of the battlespace and connectivity certainly could be profitably exploited.

Let us assume for a moment that the physical capabilities of our weapons systems remain essentially the same for the near-term future. This is not an unreasonable assumption, given the time it takes to conceive, develop, and deploy major weapons systems. Making this assumption allows us to place a lower bound on the value of NCW. However valuable we determine NCW to be in this restricted near term, it would be a tragic mistake to not pursue vigorous efforts aimed at the conceptualization and development of new weapons capabilities that allow us to better leverage the characteristics inherent in NCW. In other words, our first order of business is to see how we can make better use of our current weapons systems inventory using the concepts that are embedded in NCW.

Associated with the employment of actor entities are certain characteristics that determine their effectiveness and efficiency. Included are:

1) the targets they can engage or their engagement envelope;

2) their exposure to enemy attacks or their risk profile;
3) the speed of command and rate of engagement they can sustain (or their tempo);[82]
4) the responsiveness of forces or support units;
5) their ability to move (or their maneuverability);
6) their lethality (or the probability of kill); and
7) the extent to which their activities can be synchronized.

Adoption of NCW provides us with the ability to enlarge the engagement envelope, reduce risk profiles, increase operating tempo and responsiveness, improve maneuverability, and achieve higher kill probabilities.[83] A number of examples follow which illustrate these points.

Cooperative Engagement

Examples of enlarging the engagement envelope, increasing tempo, and reducing risk profiles can all be found in the Navy's Cooperative Engagement Capability.

The Cooperative Engagement Capability (CEC) improves our ability to conduct Air Defense. In this mission area, time is a key factor since there is a limited amount of time available to detect, track, classify, and engage targets. Engagement time is further compressed for high-speed or low-observable targets. This stresses all elements of the combat power value chain: sensors, command and control, and weapons.

CEC increases combat power by changing the relationships between battlespace and battletime. The CEC component forces currently consist of surface combatants (e.g., AEGIS Cruisers) and early warning aircraft (e.g., E-2 Hawkeye). Concepts will emerge enabling other elements, such as fighter aircraft, and ground-based missiles (e.g., Patriot Missiles or Hawk Missiles) to be employed as part of the CEC, serving to further increase combat power.

The CEC is enabled by the close coupling of an integrated communications capability in the form of the Data Distribution System (DDS), with a computational capability, in the form of the Cooperative Engagement Processor (CEP). This infostructure provides a high performance backplane which is key to increasing the velocity of information among sensor, C2, and fire control nodes. The netting of sensors generates a level of battlespace awareness that far surpasses that which could be generated by sensors operating in stand-alone mode. Shared engagement quality information is provided directly to the cognizant air defense commander, as well as to all other warfighters that have access to the CEC infostructure.

The actor entities that are linked to the CEC infostructure give the air defense commander the capability to employ forces in multiple modes. In the first mode, the netting of command and control and fire control capabilities provides the commander with automated decision support capabilities that help him identify the locations and weapons status of linked shooters. This information is combined with other battlespace information to identify the shooters that can engage each incoming target. The commander is then able to make effective force employment decisions: when to engage each target and what weapon to engage with. In this mode, the commander has centralized operational control over all connected weapons systems. Because of the short timelines involved, and the large number of decisions that potentially need to be made, a second mode has been created which automates the weapon target assignment process.

The value added by the CEC is a result of its ability to extend the engagement envelope, enabling incoming targets to be engaged in depth with multiple shooters with increased probability of kill. Furthermore, the inherent capability to engage adversary missiles by aircraft using engagement quality information generated by sensors not organic to the ship can increase the survivability of the ship by enabling it to engage without generating an electrical signature. The net result is the ability of the CEC to successfully engage and defeat threats capable of defeating a platform-centric defense. The whole is clearly greater than the sum of the parts.[84]

Beyond Line of Sight Engagement

Another example of extending the engagement envelope involves enabling forces to engage beyond their line of sight. A necessary condition for engaging targets without organic sensors or beyond line of sight of organic sensors is for engagement quality information to be generated externally and made available to the weapon or weapons system.

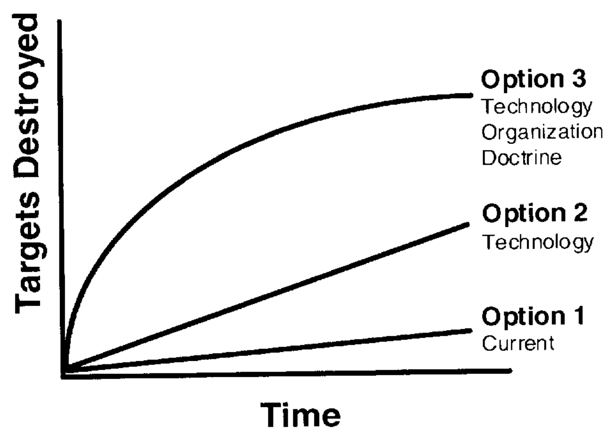
Engagement quality information consists of adequate position/velocity and identification to discriminate among blue forces, adversary forces, and neutrals in the engagement zone. This provides the commander and his forces with the information required to select a weapon with an acceptable probability of hard kill or soft kill and to employ the weapon with confidence that friendly forces are not within the effective range of the weapon during fly out or impact. Applying this to Joint operations will enable a Joint force to exploit the availability of engagement quality information to precisely engage adversary forces across the depth and breadth of the battlespace with a wide spectrum of beyond line of sight weapons (TACMS, TLAM, Enhanced Range Guns). Embedded C2 capabilities for near real time threat assessment, closure prediction, and distributed weapon-target assignment will enable the commander to synchronize employment of ground, air, and naval fires employing beyond line of sight munitions to perform anticipatory interdiction, and increase attrition of adversary forces prior to contact with ground forces.

Massing of Effects

The application of NCW to the Suppression of Enemy Air Defense (SEAD) mission provides an illustration of reduction of risk profiles and increases the probability of target kills. Figure 30 portrays the results of an analysis of SEAD.[85] In this analysis, the High-Speed Anti-Radiation Missile (HARM) Block 6 is used to suppress or destroy enemy Surface-to-Air Missile (SAM) sites, in some cases in conjunction with other shooters.

When we employ platform-centric operations (*Option 1*) during this particular scenario, we achieve virtually no kills. The HARM will still suppress the SAM sites because site operators realize that these missiles are out there, so they adjust their behavior. This is powerful in itself, but those SAM sites stayed there throughout the duration of the scenario. Consequently, aircraft that carry HARM missiles had to fly throughout the duration of the campaign, and all strike aircraft continued to be at risk. With *Option 2*, we are able to network sensors and shooters, resulting in an improved ability to generate and exploit battlespace awareness.

By employing NCW we can bring to bear other shooters capable of attacking SAM sites, such as tactical missiles (*Option 3*). The addition of this shooter capability, which requires changes in organization and doctrine, allows us to destroy virtually all of the SAM sites during the scenario. It is easy to focus on the extreme right-hand part of the curves, depicted in Figure 30, but the payoff is on the left where a very high rate of change is developed. When 50 percent of something important to an adversary is destroyed at the outset, so is his strategy. That stops wars. This is precisely what Network Centric Warfare seeks to do, and that is what lockout is all about.[86]



OPTION 1	**Current Shooter Grid Awareness + HARM BLK 6**
OPTION 2	**Improved Shooter Grid Awareness + HARM BLK 6** (Technology)
OPTION 3	**Improved Shooter Grid Awareness + HARM BLK 6 + ATACMS** (Technology / Organization / Doctrine)

Figure 30. JSEAD Mission Effectiveness

Self-Synchronization

Self-synchronization is perhaps the ultimate in achieving increased tempo and responsiveness. Self-synchronization is a mode of interaction between two or more entities. Figure 31 portrays the key elements of self-synchronization: two or more robustly networked entities, shared awareness, a rule set, and a value-adding interaction. The combination of a rule set and shared awareness enables the entities to operate in the absence of traditional hierarchical

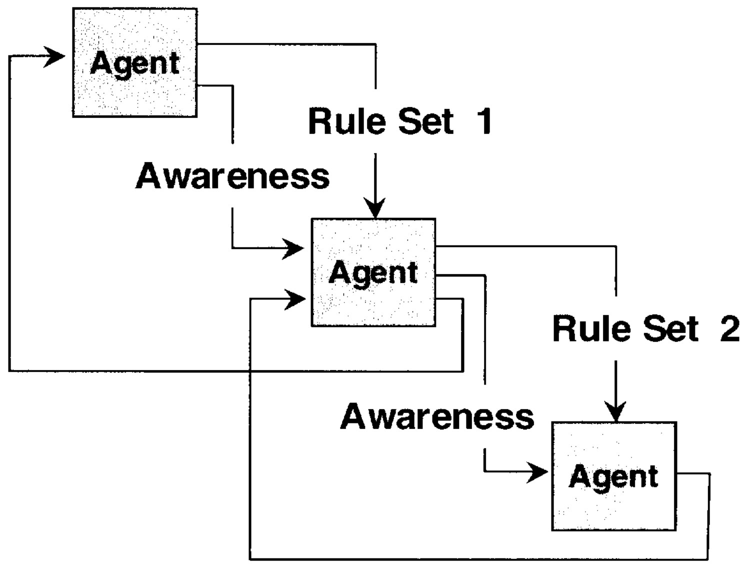


Figure 31. Self-Synchronization Interaction

mechanisms for command and control. The rule set describes the desired outcome in various operational situations. Shared awareness provides a mechanism for communicating the ongoing dynamics of the operational situation and triggering the desired value-adding interaction.

Self-synchronization can take many forms in the warfighting ecosystem. There are certain types and kinds of relationships that by their nature do not lend themselves to self-synchronization and others where the application of self-synchronization can yield significant benefits. An area where the application of self-synchronization has significant potential is a class of warfighting activities providing supporting services, such as logistics, fire support, and close air support. In platform-centric operations, the supported agent typically requests support, often via voice. Significant time is often spent communicating position information. In many cases, there are multiple distractions that complicate the exchange of information. However, as the level of shared battlespace awareness increases, new types of relationships are possible.

When the value-adding interaction takes the form of logistical support, self-synchronization provides a mechanism for pushing logistics in anticipation of need. For example, one can easily envision a situation in ground operations where near real time information on consumption of fuel and ammunition in weapons platforms (e.g., M1A2 Tanks, M2 Bradley Fighting Vehicles) combined with an agreed-to rule set could significantly improve logistical support. In fact, information on fuel consumption and ordnance expenditure is currently collected in real time with sensors embedded in F-18 aircraft. This awareness information is transmitted in real time via Link 4A to C2 and the Carrier Air Operations cell. This real time awareness enables the operational commander to redirect aircraft with fuel and ordnance to secondary targets as required. Furthermore, information on fuel consumption can be used by Air Operations to prioritize and readjust the landing queue in real time based on fuel remaining. In addition, aircraft maintainers are able to preposition required ordnance to enable rapid re-arming of aircraft. This has proven to have significant operational benefit, because ordnance needs to be moved from the ship's magazines, which takes time.

Another example of experimentation with self-synchronization comes from the U.S. Army. Recent experiences at Fort Hood, Texas, point to numerous examples where more emphasis was placed upon the use of commander's intent and where units were permitted more freedom of action to explore the ability of low-level forces (platoon and company) to operate near autonomously by retasking themselves. Warfighter exercises at both division and corps levels also indicate an increasing interest in exploring self-synchronizing forces.[87]

The most recent proof of the enormous potential of self-synchronization was provided by *Fleet Battle Experiment* (FBE) *Delta*, conducted in October 1998 in conjunction with *Exercise Foal Eagle '98*. This is an annual Joint and combined exercise sponsored by Combined Forces Command, Korea. The experiment used both real and simulated forces. The focus of *Exercise Foal Eagle* was on countering a North Korean artillery and rocket attack on Seoul and other allied positions, countering North Korean special operations forces, and improving Joint theater air and missile defense. The network-centric concepts experimented within FBE Delta linked Army and Navy sensors and shooters in ways that had not previously been considered. The result of the employment of these network-centric concepts was the generation of a very high level of shared battlespace awareness, which was exploited to increase combat power.

For example, in the Counter SOF Mission, the seemingly intractable problem of countering hundreds of North Korean special operations boats was dealt with on a timeline previously not thought possible. The application of network-centric concepts enabled Army helicopters, P-3s, LAMPS, AC-130s, and land- and carrier-based aircraft units to share a common operational picture and to synchronize their efforts from the bottom up. This self-synchronization demonstrated the capability for leakers to be reduced by an order of magnitude and for the operational mission to be accomplished in half the time required, compared to traditional platform-centric operations. Figure 32 demonstrates the significantly increased combat power that can be generated with network-centric operations.

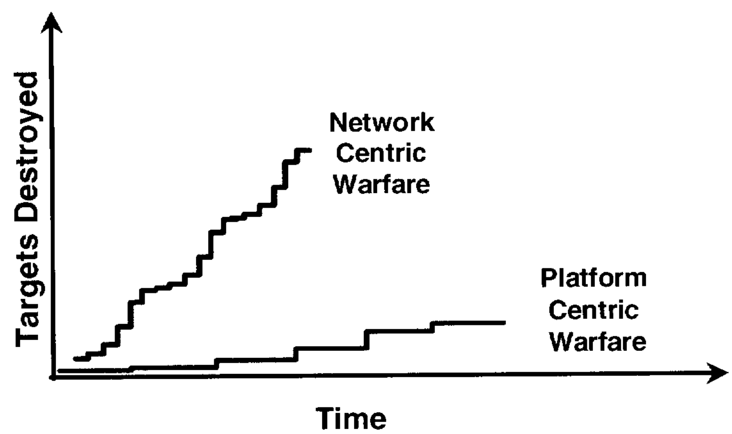


Figure 32. Network Centric Warfare—
Fleet Battle Experiment Delta

The operational impact of this significantly increased combat power at the tactical level is that forces that otherwise would have needed to be held in reserve to deal with leakers (SOF forces that penetrate the defensive forces) can now be reassigned, changing the complexion of the battle. This is an example of the potential for network-centric operations at the tactical level to have operational and strategic implications.

When reduced to these elementary terms, it sounds so simple, but it had never been done before and the impact was profound. This seems to characterize all great advances.[88]

Tempo and Responsiveness

Short of self-synchronization, there are a variety of ways to achieve less dramatic, but meaningful increases in tempo and responsiveness. Increasing tempo and responsiveness both involve reducing timelines while maintaining or increasing quality. These could involve reducing the:

1) time between target detection and delivery of munitions on target;
2) time to plan; or
3) time necessary to form and equip forces to conduct operations.

Figure 33, Operational Gains of Digitization,[89] shows the nature of the operational impact of reducing the time it takes to plan, respond to a call for fire, mount an attack, and move to contact. The U.S. Army's Division XXI AWE produced dramatic results by killing over twice the enemy in half the time at over three times the battlespace with 25 percent fewer combat platforms using Information Age technology.[90]
The examples that follow illustrate the value of increased tempo and/or responsiveness in three situations: fire support, engagement, and logistics.

Providing fire support involves responding to requests for fire, forwarded by multiple warfighters dispersed across the battlespace, given a finite set of weapons

Activity (Before/After)	OPTEMPO	Lethality	Survivability
Plan Development (Div) **72 v 12 hrs**	☑		
Call for Fire **3 v 0.5 min**		☑	
Deliberate Attack (Co) **40 v 20 min**	☑	☑	☑
Hasty Attack (Co) **39 v 112 Red Loss**	☑	☑	
Defense in Sector **Loss v Win**		☑	☑
Movement to Contact **91 v 128 Red Loss**		☑	☑

Figure 33. Operational Gains of Digitization

which are (most likely) also dispersed geographically across the batttlespace. Multiple factors conspire to complicate and potentially slow down the command and control process and reduce responsiveness to these urgent requests. These factors include simultaneous requests for fire, requests for fire that exceed available resources and the dynamic nature of the requests, and the capabilities (range, firing rate) of shooting assets. In approaching this problem, a value can be assigned to each call for fire, corresponding to the value of engaging the target by time T_{max} beyond which the value is dramatically reduced. The value assigned can be negative, which would correspond to blue losses that could result from supporting fires not being provided by time T_{max}.

Providing responsive fires requires that a set of weapon-target assignment decisions be made. Over a discrete time horizon (which is variable) the C2 node attempts to maximize the overall value of responding to calls for fire, while simultaneously minimizing the cost (e.g., why use a tactical missile if gun fire will do?) and potentially considering conserving fires (e.g., may or may not want to fire all tactical missiles in the first 30 minutes of battle; may want to if they are being used to take out high-value assets such as enemy air defense installations).

As the number of simultaneous calls for fire and the number of potential shooters and types of weapons increase, the target assignment problem becomes more difficult. Beyond some threshold, a human decision maker is overwhelmed, resulting in sub-optimal assignments, or worse, unacceptable delays in allocating fires (an example of value subtracting C2).

Consequently, the use of automated or semi-automated decision aides for weapon target assignments, robustly networking sensors, C2 nodes, and shooters, can increase combat power. The U.S. Navy in the Fleet Battle Experiment Series is exploring this concept. During *Fleet Battle Experiment Alpha*, an experimental concept, referred to as a *ring of fire* was employed. The ring-of-fire concept explores the potential for a robustly networked force of sea- and air-based shooters employing automated pairing of weapons to targets, automated force-wide weapons inventory, and integrated airspace deconfliction. These emerging capabilities will help sea-based shooters increase lethality against both time-critical targets and moving targets.

Another example of achieving improved responsiveness involves en route mission updates and/or target assignments enabled by a robust network that links shooters to C2 nodes. This concept was explored by the U.S. Air Force in *Expeditionary Force Experiment '98* (EFX '98) by launching a B-1B bomber into a broad engagement zone without specific targets, and then providing the B-1B with en route targeting and weaponeering information via tactical data links. This approach provides more flexibility and increased responsiveness (and perhaps improved lethality) by allowing the C2 node to include targets that may not have been detected and identified prior to takeoff and by providing more up-to-date location information by allowing the C2 node to choose targets based upon a more current assessment of the situation.[91]

The JV2010 concept of Focused Logistics aims at providing support that is more responsive and timely. A new operational capability serves to illustrate what lies ahead. To manifest 200 soldiers for air transport can take over 8 hours employing traditional techniques. During *Exercise Cobra Gold '98*, the use of smart-card technology and portable sensors enabled 200 soldiers to be manifested in 2 hours while the manifest information was loaded directly into the Global Transportation Network (GTN). Additional process changes have the potential to reduce the total manifest time to under an hour.[92] The result is both accelerated deployment of troops and material and increased in-transit visibility that serves to allow a commander to respond more quickly and increase tempo to the limit allowed by the logistics situation.

Implications

The effects of a series of improvements, such as illustrated above, are highly synergistic, making the resulting force much more effective and efficient. In fact, this synergy allows NCW, for the first time, to provide us with the possibility of moving beyond a strategy based upon attrition, to one based upon shock and awe.[93] Shock and awe are achieved not simply as a function of the number of targets destroyed, but as a result of the destruction or neutralization of significant numbers of critical targets within a short period of time and/or the successful targeting of the right target at the right time.

The key to this fundamental transformation from attrition to shock and awe lies in the increased ability to integrate. Integration must take place in a number of different dimensions if we are to be successful in realizing the potential benefits inherent in NCW. While increased connectivity enables this integration to take place, it remains only a potential capability until we develop operational concepts, command approaches, organizations, and the like that specify the processes that serve to integrate our tasks and activities over echelons, over time, functionally and geographically.

The engagement envelope for a particular actor is often constrained more by limits on engagement quality data and by existing doctrine about what targets (type and location) may be engaged, than by the range of the available weapons. Both of these artificial[94] constraints can be eliminated with the adoption of NCW.

Being in harm's way is not always intentional. Actors may find themselves placed in harm's way because of a lack of battlespace knowledge, maneuverability, or covering fire. In fact, it has often been the case that actors were placed in harm's way simply to gain information about the battlespace. For example, during the Cold War, U.S. Navy submarines were sent in harm's way to collect intelligence on the capabilities of Soviet Naval Forces.[95] Given the potentially significant increases in battlespace knowledge and engagement envelopes, and improvements in maneuverability that result from the adoption of NCW, actors will find themselves in harm's way only when it is absolutely essential to complete the task at hand. When placed in harm's way, NCW will provide them with an increased ability to be protected and/or removed from danger.

The ability to move depends, in large part, upon the size of the actor entity which, in many cases, can be reduced significantly by NCW-related concepts of reach-back and just-in-time logistics support.

Tempo, the pace of operational activity of forces in the battlespace, speaks to the intensity of the engagement and how rapidly the proper targets can be engaged. This is, of course, key to achieving shock and awe. The current cyclic nature of command and control limits decision throughput, and the separation of planning from execution limits tempo. Current limitations in the engagement envelope limit maneuvers. The ability to be better integrated over echelons, over time and functionally, is the key to achieving a much higher tempo, particularly given the expected increases in engagement ranges and the improvements in maneuverability. Achieving better integration over echelons will reduce the time it takes to transform a change in commander's intent into action or to implement a decision. The move from a cyclic C2 process that performs planning and execution sequentially and is characterized by a period to a more continuous process that merges planning and execution, will result in our ability to generate much higher tempos. Finally, the greater empowerment of actors will increase the decision-making resources available, allowing us to take advantage of parallel processing, and hence reduce or eliminate yet another factor that limits tempo.

Kill probability can be improved by obtaining more accurate information about targets and better matching weapons and targets. NCW approach helps us in a number of ways by being able to move quickly, getting the right information to the right place, and allowing us to have a wider selection in our assignment of a weapon to a particular target.

NCW offers a promising opportunity to both improve the effectiveness of military operations and to reduce their costs (measured in terms such as number of casualties, collateral damage, and strategic fallout). It promises to raise the art of war to new heights and enables us to compress military campaigns into time frames to be more consistent with our 21st century world.

The Entry Fee

The entry fee for Network Centric Warfare is an infostructure that provides all elements of the warfighting enterprise with access to high-quality information services.[96] What separates the future from the present will be the provision of nearly ubiquitous information services to all elements of the warfighting enterprise. These elements include deployed U.S. forces, supporting forces based in the United States, and allied and coalition partners. The required quality of service will vary as a function of the demands of each MCP across the enterprise as portrayed in Figure 34.[97]

At the high end of the performance spectrum is cooperative sensing and engagement of high-speed targets. Accomplishing this requires high data rate and very low latency information transport capabilities. At the intermediate level are various types of command and control activities, such as coordination of tactical combat operations, which can tolerate information delays on the order of seconds. These operations are typically supported by tactical data links. Other types of command and control and logistical operations, such as operational planning, are not nearly so time sensitive. For example, information about the contents of a large container ship, which may take tens of days to transit from a point of embarkation to debarkation, most likely can tolerate delays on the order of minutes. Similarly, the wide variation in the importance and

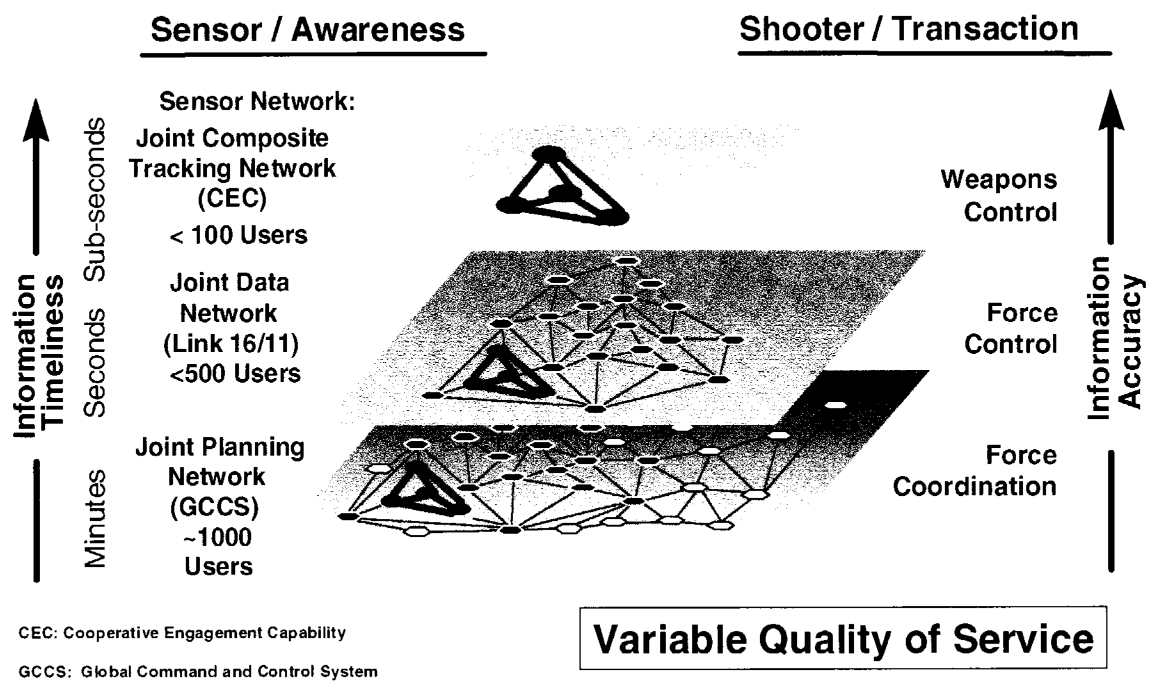


Figure 34. Variations in the Quality of Service Across the Warfighting Enterprise

urgency of e-mail traffic lends itself to various levels of latency and precedence.

There is a direct relationship between the velocity of information and the speed and tempo of operations across the warfighting enterprise. In the previous sections, we have seen that one of the primary motivations for providing high-quality information services to the warfighting force is to be able to achieve a large increase in the speed and tempo of operations. Such an increase is a prerequisite for many of NCW-based concepts of operations under discussion.

At a high level of abstraction, we can view the infostructure as an integrated network of communications and computational capabilities. The computational nodes and the communications links convey the seamless integration of computing and communications into a single *backplane*.

Our warfighting backplane will employ multi-mode data transport capabilities, including military and commercial satellite communications capabilities, multiple types of data links and radios, and commercial information services. These data transport capabilities will both provide users with access to appropriate elements of a distributed computing environment, as well as providing the interconnecting fabric for a wide range of computational and storage capabilities. The backplane supporting the infostructure will employ a multi-tiered architecture for information transport and processing to increase capacity and improve interoperability. By exploiting emerging technology for providing quality of service across Internet protocol

(IP)-based networks, the architecture of the infostructure will enable multiple stand-alone networks to be integrated into an adaptive and reconfigurable network-of-networks.[98] This operational flexibility will enable commanders to plug and play sensors, shooters, command and control, and support capabilities into task-organized combat packages, including appropriate collections of sensors and weapons.

A core technical capability for enabling variable quality of service information services and effectively exploiting finite information transport and processing capabilities is transaction-based prioritization of information transport and processing. In the current environment, several types and kinds of independent voice, video, and data networks (e.g., Defense Information Infrastructure, Tactical Digital Information Links) operate as independent networks for multiple reasons. One of the primary drivers for separate networks is the need to meet required timelines for information exchange. As was described previously, this is the situation that exists today, where tactical data links, such as Link 16 and CEC, operate with protocols which are separate and distinct from the protocols employed with Transmission Control Protocol/ Internet Protocol (TCP/IP)-based networks, such as the Secret Internet Protocol Router Network (SIPRNET). One of the primary drivers for separate networks is that until recently, IP networking technology could not enable quality of service to be linked to transaction type. The technology now exists to solve this problem.[99] In other cases, security requirements, combined with the limitations of existing technology, conspire to dictate separate networks, as is the case with the Sensitive but Unclassified Internet Protocol Router Network (NIPRNET) and the SIPRNET.

Since future warfare will rely heavily on increased connectivity among sensors, command nodes, and weapons, network security will be high priority. Integrated capabilities for information protection will provide the network-centric force with assured high-speed access to the information required to dominate across all levels of conflict. With the advent of information warfare techniques, it is no longer necessary for our adversaries to have direct physical access to our infostructure in order to attack us. We can be attacked from anywhere in the world, any time of the day or night. Enhancing the security and computer network defense capabilities of both the classified and unclassified elements of the infostructure will ensure that high-quality information services are available to the warfighter and supporting elements when and where they are needed.[100] An infostructure must be properly managed to ensure that it is dynamically tuned to meet the warfighter's needs. Enhanced capabilities for network operations will provide operational commanders with a real-time picture of the status of the backplane. This picture, when combined with advanced capabilities for intelligent network management, will provide commanders with the flexibility to tune the infostructure and synchronize information transport and processing with military operations.

Commercial information technology is driving the convergence of technologies for voice and data services. This technology will enable data traffic to be provided with the reliability and quality of service associated with dial tone, as well as new and exciting capabilities that we have not yet imagined. The technologies that emerge from the commercial sector, when augmented with specialized information technologies developed by the DoD, such as high-end encryption, low-probability of intercept and detection communications, and specialized intelligent agents, will provide the brick and mortar for our "Global Information Grid."[101]

The acquisition, deployment, and operation of the infostructure are and will continue to be an ongoing process. New and emerging technologies will continue to create exciting opportunities for both suppressing costs and improving performance. Integrating these technologies with existing systems and capabilities will be one of the most significant challenges we face as we move toward enabling a network-centric force. The next chapter is devoted to a discussion of each of the elements of an MCP, and the nature of the changes that will be required to be able to conduct network-centric operations.

Implications for MCPs

Innovation is inextricably tied to changing long-held precepts about the way we do things. Culture, rules, and tools determine how things get done. The concept of a mission capability package (MCP) is a useful way of describing and discussing a way of doing business. Multiple terms have been used throughout DoD to describe this basic concept. These include doctrine, organization, training, materiel, leadership, and personnel (DOTML-P) and doctrine, organization, materiel (DOM) (ACOM's characterization). An MCP consists of a concept of operations, command approach, organization, systems, and people with a prescribed level of expertise. Implicit in an MCP is the nature, distribution, and utilization of information. To make MCPs based upon NCW all that they can be, we need to rethink each and every component of an MCP. We will discuss the nature of the changes that will need to be made in each of an MCP's main components.

Concept of Operations

The process of building a new MCP begins with the development of the concept of operations (ConOps). In looking to see if a ConOps is really based on NCW, one needs to see if it takes full advantage of all the information and forces (sensor and actor entities) that could be available given the timeliness requirements of the mission. NCW-based ConOps should be focused on identifying and employing these entities in a manner that dominates the adversaries (or in the case of Humanitarian Assistance Operations, in a way that fully anticipates environmental factors) by determining the best time, places (targets), and methods (hard or soft) to intervene to achieve the desired end.

Command Approach

The command approach(es) selected or developed for the MCP should reflect the characteristics inherent in the ConOps. The nature of the command decisions to be made by battlespace entities, and those that are delegated to battlespace agents, need to reflect both distribution of battlespace knowledge over time and the time lines associated with the ConOps. In general, one would expect that in an NCW-based MCP, command decisions would migrate closer to the pointy end(s) of the spear. Ironically, this could at first glance seem to be coming full circle to the days when communications over any distances were very slow and limited, and local commanders acted almost autonomously. The major difference, of course, is that now an autonomous unit is really not truly autonomous because its behavior is heavily influenced by its view of the COP, and its perception of the commander's intent, even as they might change.

Organization

Form must follow function if NCW-based MCPs are to achieve their potential. The organizational form(s) designed by the MCP must be based upon the ConOps and Command Approach. Simply put, the organization should be designed to facilitate the flow of information and materials needed to carry out the tasks at hand. There should be no organizational barriers or speed bumps that degrade performance. NCW organizations therefore need to be *born joint* to ensure that all of the available information and assets can be brought to bear on the task at hand. It is anticipated that NCW-based organizational forms will be more agile than current ones. Perhaps operational organizations will become virtual ones, formed specifically to accomplish a particular set of tasks for just as long as necessary and then cease to be, with their resources going back into the mission infrastructure, waiting to be assigned once more. Depending upon the dynamics of the battlespace and the nature of the task at hand, these virtual organizations might exist for minutes or months.

Infostructure Systems

Infostructure systems will provide key capabilities (bandwidth, processing power, stored information, decision aids, and agents) and need to be better designed to support battlespace entities as they interact much more closely than ever before. The increased use of decision aids and battlespace agents will make it more important for the systems to be thoroughly tested before deployment. Just like organizations, their job is to enable and facilitate, not to get in the way. Legacy systems, designed as stovepipes optimized for one way of doing business, will need to give way to systems that are optimized to share and exchange information (with appropriate security). Individual systems will no longer be effective unless they can contribute value as part of a larger federation of systems that constitute the infostructure.

NCW requires team play, not only among battlespace entities, but also from the systems and organizations that support them. Interoperability, security, and the teamwork they enable need to be part of the initial design of every system. They cannot be added later. Testing systems will become far more complex since the focus will not be on the performance of individual systems, but on the performance of federations of systems.

People

People are central to any MCP, for it is the people that turn concepts into realities and fill in the gaps and inconsistencies within and among organizations, systems, and battlespace knowledge. Collectively, people create and maintain culture, so in order to make NCW MCPs work, the force needs to be educated and trained to develop NCW attitudes and expertise. NCW doctrine needs to be written to support this process. NCW requires significant changes in mindset and much greater understanding of the information that is available and the processes, tools, and agents that turn this collection of information into battlespace knowledge. Individuals will need to know more about the battlespace and the roles of others in that battlespace. Doctrine will need to be developed and/or modified to emphasize the principles inherent in NCW, the new roles that battlespace entities will play, and the nature of their interactions. It will also be extremely important to give people an adequate opportunity to build trust in the information and tools that will be developed, and to develop a capability to absorb new and enhanced capabilities as they become available.

Coevolution of MCP

The process of engineering an MCP needs to encourage and facilitate the coevolution of its component parts right from the start. The melding of a ConOps, C2, organization, doctrine, weapons and infrastructure, systems, and personnel into a coherent MCP is essentially an interdisciplinary learning process that is one part discovery, one part testing, and one part practice. It could be said that teamwork is the co-pilot of NCW—from the conceptualization of new MCPs, to their refinement and demonstration, to the acquisition of needed components and the development of needed personnel, to their perfection through experience and practice.