Cutting Through the Fog with Knowledge Superiority – Employing the System-of-Systems Through Operational Engineering, The Edge of the Future

Russell E. Bryant and John E. Flynn
Program Executive Office (Theater Surface Combatants)
2531 Jefferson Davis Hwy
Arlington VA 22242-5170
(703) 602-1990 x422 (703) 602-2287 x300
Russell.Bryant@navy.mil FlynnJE@navsea.navy.mil

Abstract

Many discussions and articles address the business and military changes supporting implementation of Joint Vision 2010 and its system-of-systems approach. The dynamics of international military operations and commitments, coupled with accelerating information technologies, can lead to confusion and uncertainty. Customary rules recommend caution, even stopping, when confusion and uncertainty are present, yet the needed changes counsel toward accelerated efforts. Currently, system engineering does not completely address delivering "operational war fighting capabilities", nor foster commanders' confidence to fully exploit those capabilities upon delivery.

Acquisition reform supports accelerating delivery of systems. Likewise, accelerated delivery of "war fighting capabilities" within any opponents' fielding and deployment cycle is imperative. Technical advances in modeling and simulation, utilization concepts, and innovative evaluation methods create an opportunity to facilitate co-development of doctrine, operations, and training prior to producing hardware systems. On-line simulation and evaluation tools can overcome the need for physical systems.

Specifically, this paper lays out the opportunity to evolve System Engineering to another level, Operational Engineering, which leverages from the modeling and simulation environment, prior to hardware production. That modeling and simulation paired with co-evolution of procedures and on-line analysis will produce a trained customer base, fully prepared for deliveries of "operational war fighting capabilities".

Introduction – *Perspective*

In the active environment of today, greater emphasis is being placed on increasing worker and employee contributions and efficiencies. The efficiencies and contributions run the gamut from mundane: tossing out dated, unused forms; to, grandiose: complete re-engineering and re-organization. These are generally presented as opportunities waiting to be found within the complete spectrum of events and processes within an organization. Within the engineering and acquisition community, one alluring mantra regularly presented is that of the contribution of the integrated chip (IC) and the computer. These represent a significant component of all pieces, parts, and tools of the future system-of-systems often included within the title of 'network centric warfare' and implementation steps of Joint Vision 2010's tenet – Full Spectrum Dominance.

Changes encompass uncertainty and confusion, frequently resulting in efforts to preserve the status quo. Technologies are available to adversaries and allies alike, facilitating non-linear asymmetric threats and leaps in capabilities. The rate of technological change, and increasing worldwide availability of technology and information, has serious war fighting implications. Previously controlled technologies are becoming more available and war fighting systems face accelerated obsolescence, this calls for improved delivery of fully developed products and capabilities to retain war fighting and conflict superiority.

Unfortunately, the focus may too often emphasize acquisition without commensurate focus on end user utilization. The primary focus is on the technology aspects of the systems and components, at the expense of the soft items included in logistics, e.g., manpower training and operational doctrine development, that underpin operational proficiency and superiority.

Systems and components provided to our customer, the Combatant Commander, are but one aspect of the system-of-systems that is both being built and evolving at the same time. Weapons systems consist of the hardware, computer programs, and combat system personnel. These personnel operate, maintain, and interact with the systems and employ Tactics, Techniques, and Procedure (TTPs) and Concepts of Operations (CONOPS).

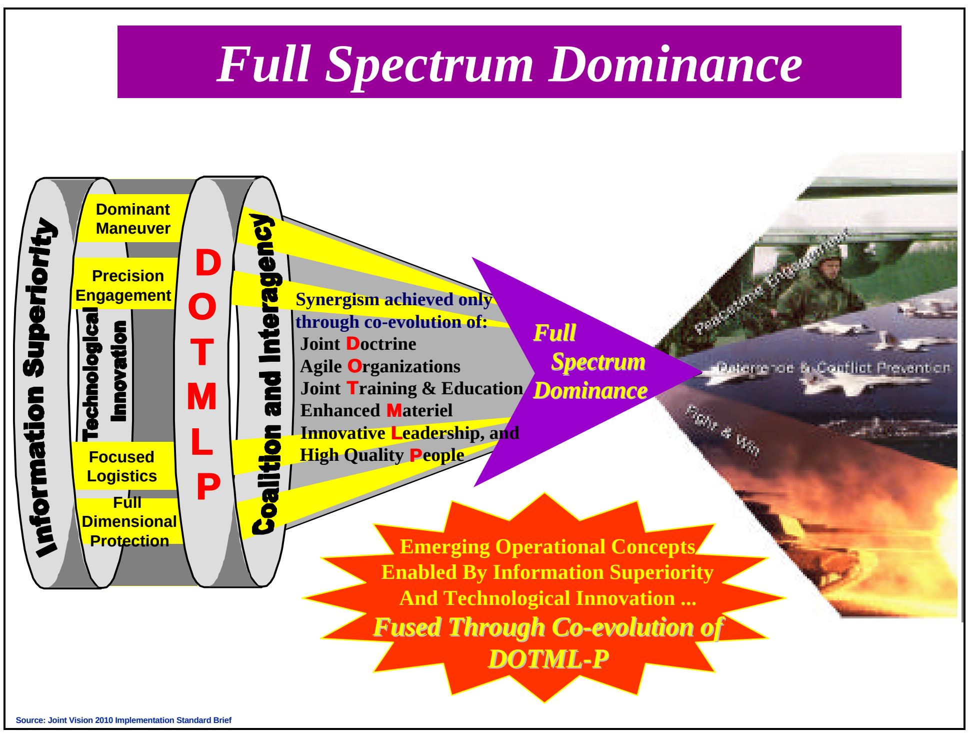


Figure 1. Full Spectrum Dominance

Joint Interoperability is the linchpin that ties the system components and personnel into an effective family of systems for the combat system customer. Joint Interoperability is advanced through the use of visualization tools; service and joint battle laboratories; service and joint battle experiments; re-configurable distributed design, engineering, and test platforms; research investments; and, modeling and simulation. Given that in future conflicts, U.S. forces will likely operate as part of a coalition, the engineering and acquisition process must include this in an operational engineering development environment. All these points are invoked by Figure 1.

As currently practiced, system engineering does not delivery fully operational war fighting capabilities to the combatant commander. Yet, as the end user he is an essential and integral part of the System Engineering process, and must be included. Concepts of operations, doctrine, interoperability, and training must co-evolve with the knowledge engineering prior to metal bending engineering by initially using advanced visualization and modeling and simulation (M&S) to gain tactical employment insights in the early acquisition phases. This approach will support the planning, funding, and acquisition cycles to meet national strategies through real time operations analysis via the distributed Defense Information Infrastructure/ National Information Infrastructure (DII/NII) network capabilities. These two pieces (co-evolution and near real-time analysis) can produce a trained and operationally ready user base, as well as test and validate existing and proposed operational plans and concepts.

History

A great source of ideas and inspiration on war and leadership, Carl von Clausewitz [Howard & Paret, 1977] served as a Russian and Prussian Army Officer of the Napoleonic era. During that time warfare was characterized by frontal confrontation of force against force via massed combined arms formations. Yes, there were lots of other smaller types of engagements, spies, cavalry, artillery, etc. included within the forces, the principal model of nation against nation was large force against large force.

Recent history likewise has flavored this same mixture. As a nation, the U.S. approached the planning and preparation for confrontation/war with the Soviet Union on a basis similar to that of Clausewitz, i.e., our massed forces against those of the Soviet Union on air, sea, and land. The calculus was the numbers of tanks required to stem the Russian offensive through central Europe. This model of planning and confrontation has been removed from sole primacy with the fall of the Berlin Wall and collapse of the Soviet Union in 1989. Where the Russian Bear once stood there now are many shallows and restricted maneuvering circumstances. Literally the world is viewed differently and there are a multitude of engagements seen, few, seemingly connected. John Barry [2000] pointed out that preparing for the future by considering only the last war may be shortsighted, the services must also identify and analyze the current patterns while preparing for the future. The ability to adapt to changing circumstances and to shape them with agility linked to capabilities will have a significant role in retaining American war fighting dominance.

Desert Shield and Desert Storm demonstrated that the services planning and execution of engagements and procedures of the 70’s and 80’s are evolving to new areas of uncertainty, models, and execution. Some might call this a move into a fog preparation and planning, akin to the friction (and fog) of war that is portrayed by Clausewitz and his proponents in the discourses of war and intelligence. A fair question maybe whether Clausewitz has become out-of-date, and his observations are in need of major re-interpretation. As shown buy Beyerchen [1997 & 1998], he offered many ideas which provide an enduring foundation on which to build. There occasionally must be modifications made to the structure built above that foundation. The emphasis for improved information, coordination, and knowledge represents that modification. To gain that knowledge, there must be an emphasis on learning and becoming 'comfortable with the risks' of uncertainty and friction.

The primacy of massed forces is no longer a given, the services still face the enemy in many forms. Paraphrasing a dojo aphorism, the objective now is *maximum effectiveness for minimum resource expenditure*.

Safe Navigation

Navy and maritime heritage has produced guidelines and rules to transmit the wisdom of experience and lessons of many losses upon byways of the world. Some, such as the custom of rendering assistance to a sailor in distress, are of long standing tradition that are considered outside, maybe even above, the traditional maritime rules and regulations. Many of these have been codified in the Navigational Rules [72 COLREGS, 1995] which cover the basic aspects of maritime law and safe navigation.

It is via the tools associated with the rules that the friction and uncertainty –the fog of war – leads to the next buoy in the channel. Traditionally, when prudent mariners are confronted with uncertainty or the loss of key information, they still beat the burden of making knowledgeable decisions. What do they do? They return to the time tested, proven training and experience, they: slow, commence making fog signals, and post additional lookouts. In more recent years with improvements to navigation aids and systems, these points are augmented with electronic aides: radars, loran, omega, ship's inertial navigation system (SINS), and most recently global positioning system (GPS). The older methods: sun shots, local apparent noon (LAN), and evening stars, are still taught, and used; more for understanding the new systems, than lack of will to break with traditions (that worked). This may even reflect a lack of confidence in the new systems.

Yet, new technologies offer to remove fog induced uncertainty. New and improved sensors and processing capabilities offer assistance, i.e., infrared imaging that goes beyond the basic targeting and tracking; reconstruction of two-dimensional imaging into synthetic three-dimensional representations; multi- and hyper-spectral imaging for environmental and shallow water characterization and evaluation; and, on-line retrieval and data mining of image and mapping databases. These offer the chance of full data integration to provide a more complete set of insights and understanding of the situation. These new sources may introduce, rather than remove, uncertainty, thus a trained and experienced team of operators and acquisition professionals with a high level of understanding may be able to overcome that uncertainty, and achieve faster operational execution. The next buoy in the channel.

As the system-of-systems/network centric warfare capabilities of JV 2010 are developed, all the associated components and system aggregates are continually impacted by the increased computing power and price reductions predicted by Gordon E. Moore's Law. The introduction points of the silicon chip are thoroughly pervasive in the battlefield systems and components, even into the foundation development and training areas that produce and develop the future operators of the system-of-systems. The complete team of operators and acquisition professionals are part of the systems engineering effort striving to produce this system-of-systems and its associated capabilities. For this system-of-systems to be the enabler of the capability of 'dominant battlespace knowledge', which will cut through the fog of uncertainty and allow acceleration, it must develop and empower the users, maintainers, and producers all at the same time. Fostering linkage of users and producers with systems capabilities is part of the intent of this paper and its recommendations.

The linkages are being tested via experiments with varying degrees of success. The Army Force XXI experiments, Louisiana Maneuvers, the Naval Fleet Battle Experiments (FBEs), and the Marine Corps Sea Dragon initiatives are all within this arena. During the last few years, the Naval team has successfully completed six FBEs and the Warrior series. These have refined and advanced Naval knowledge, with the goal of improving the Combatant Commanders (Commander-in-Chiefs (CINCs)) operational war fighting capabilities.

Getting the hardware correct and ready to use without the capabilities of the personnel to employ, use, and take initiative is still not successfully completing the headquarters delivery mission. It is not supporting the Combatant Commander with a fully ready force of trained personnel fielding interoperable weapons systems. The Naval Sea Systems Command mission is: "We are ships! We develop, acquire, modernize, and maintain affordable ships, ordnance, and systems that are operationally superior so that our Sailors and Marines can protect and defend our national interests and, if necessary, fight and win." [Sterner, 1997].

Leading From The Front

"One of Nelson's great strengths as a commander was his confident willingness to amend established doctrine when necessary. Before Trafalgar he explained, as he put it, 'not only to the commanders of the fleet but almost to every individual how he was going to deviate from the standard battleline . . . to approach the enemy line in two perpendicular lines of his own to cut it into three sections that could be annihilated in detail.' . . . All approved –it was new –it was singular –it was simple! His captains put the plan into effect in the greatest victory in the Royal Navy's history." [NDP-5, 1996]. This provided an amount of certainty for understanding and comfort to the 'combatant commander', though it did not remove all the uncertainty of precise steps to be taken to overcome the opposition in the engagement by the specific war fighter. Understanding the Commanders intent permits the rapid selection and execution of the most likely to succeed ACTION as a matter of reflex, compared to the laborious request for direction and associated delay.

Having the commander on scene has basis in traditions and acceptance. Does leading from the front hinder or promote war fighter initiative for fulfilling the Commanders intent? A point made by Admiral J. Paul Reason [1998], former Commander-in-Chief, Atlantic Fleet, is to allow the operators to provide and test solutions for improvements –the "What, Where, and When"; empowering of the operators enables the "How"; and, the foundation is the communication, and understanding, of the Commander's intent – the "Why." All aimed at faster operational execution.

The manning training, concept of operations, and the logistics tail must be prepared and presented to the end user as a complete package. In the faster paced environment of operations today, the end user will be the "leader" on-scene. The end user must know and understand the concept of the operations as envisioned by the Commander – this is training. The Commander's intimate involvement in the training process, in turn, creates mutual trust. This trust then can be reflected in the Rules of Engagement (ROE) communicated to the front line units. Unclear, ambiguous, erroneous, false assumptions and the consequences of error are the basis for the development of restrictive ROE. When required to respond under a restrictive ROE, the war fighter can be at a loss as to the "correct" course of action and may, in some cases, elect to withdraw or chose inaction rather than aggressively confront the enemy. While the silicon chip and computer are parts of the components for understanding and execution of Commanders intent, they must not become the sole delivery product – compared to the mission capabilities. Instead, they are assistants in the process of developing and testing the TTPs, CONOPs, and Joint Interoperability of war fighter mission capabilities prior to system receipt.

Lord Nelson on the quarterdeck of his flagship, HMS Victory, represents a view of the model of both leading from the front and encouraging subordinate commanders' initiative. A more recent example is the Navy Battle Groups operations in the vicinity of the Taiwan Straits during March 1996 as an American show of support for Taiwan against main land China. During that evolution, plans and proposals were exchanged and reviewed within the national and Navy command structure, using the existing ship-to-shore computer networks links, Video Tele-Conferences (VTCs), and exchange of power point briefs to facilitate faster collaborative planning. This allowed 'commanders' at several levels to review, coordinate, and resolve issues and desires 'on-line' and prior to the commencement of the encounter, much like the dinners of Lord Nelson. Intent, including nuances, was communicated and understood. Additionally, it shows how technology can assist in accelerating decision-making through discussion and evaluation of the underlying risks as well as reducing the detailed labor of the planning. An example is the accelerated, pro-active and reactive evaluation of alternatives as stated in the FBE-Charlie: Quicklook Report [1998] of the prototype Area Air Defense Commander (AADC) module at Johns Hopkins University, Applied Physics Laboratory during Theater Missile Defense Initiative 98.

This level of communications capability presents the war fighter a vast amount of knowledge – material the war fighter must sift to reach the correct solution to the existing and developing situation. A potential downside to increased collaboration and knowledge sharing might be the lack of delegation to act on knowledge. Wading through information clutter is not a trivial challenge as the war fighter strives toward knowledge and understanding.

This Taiwan Straits example while showing tactical through strategic involvement, also demonstrates the complexity and confusion that new connectivity technology generates, when several Commanders are present. Whether tactically – literally, or strategically – virtually, that presence is only assured through connectivity. The fog of uncertainty may return with loss of connectivity (whether degradation or complete loss), possibly causing paralysis or degraded mission performance absent understanding of ultimate goals and intent. In the future this knowledge and understanding can be gained via the war games, service exercises, hardware in the loop events, and the M&S experiences of the operational engineering environment. They will prepare and develop the operators and acquisition professionals team. That team will be armed with knowledge-based experiences and models to employ and operate the system-of-systems at an accelerated pace.

While the Taiwan Strait example cites the military technology aspects, there are others – diplomatic and political - covered elsewhere, e.g., Douglas Porch [1999], War College Quarterly, and is outside the immediate topic of this paper. The demonstrated technology will ultimately be available to the individual platoon, artillery company, aircraft, or ship allowing accelerated course of action selection to produce decisive effects on enemy forces and critical nodes. By providing the near real time analysis tools to the individuals, the opportunity to see patterns in the uncertainty and fog, and potentially provide an on-line, near real time 'tactical joint warfighting analysis center' (T-JWAC) capability is feasible. What has until now been performed on a strategic level, is in the early stages of supporting tactical level, i.e., joint strike forces with systems such as the Land Attack Warfare System (LAWS). This assists in turning data and information into true knowledge and understanding, and through successful engagements to produce the desire effects, e.g., the demanding and receiving of time sensitive targeting assistance by U.S. forces on critical enemy nodes. To make this system-of-systems truly work, the team of operators and acquisition professionals must embrace operational engineering.

"Just-In-Time" Training

Information technologies offer this capability, but the true enabler of the system-of-systems mission capabilities is the team of operators and acquisition professionals. Reliance on the system by itself is the old model, and offers but one of many solutions for its future use. That

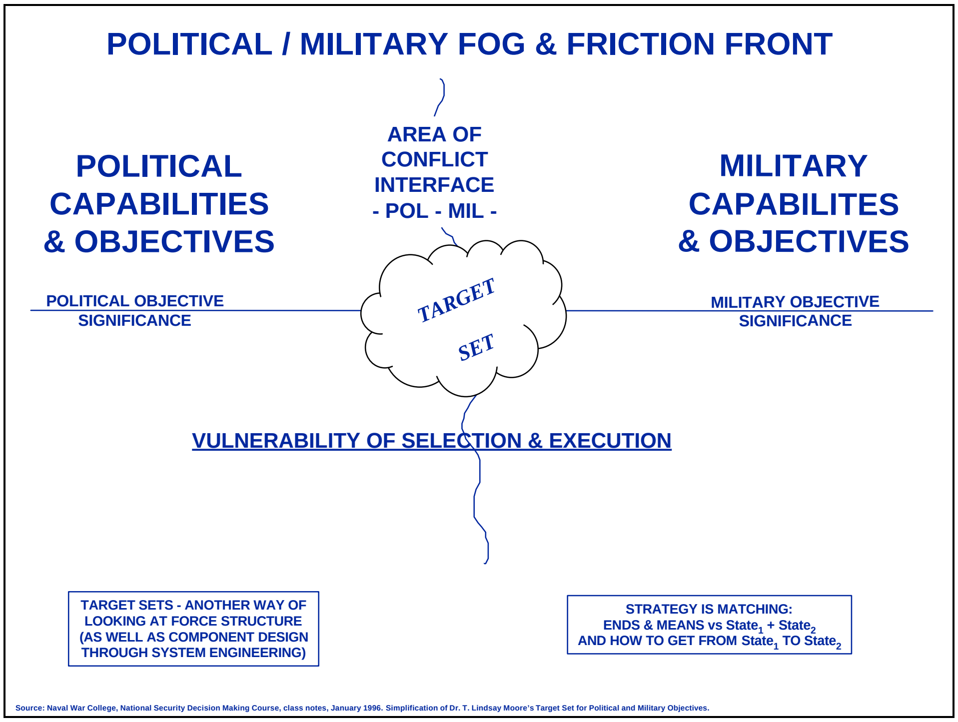


Figure 2. Political / Military Fog & Friction Front

future will continue to be one of confusion and uncertainty for employing the system-of-systems mission capabilities against the military and political set of targets and objectives generalized in the axis set of Figure 2. [Moore, 1996] In learning to understand the specific mission intent and outcomes, the operations and production personnel should understand the knowledge based warfare coordinate system outlined in Figure 3. [derived from Strickland, 1996] The team will need to master even broader skill levels as shipboard personnel numbers are reduced aboard current (via smart ship efforts) and future combatants (such as DD21), and the acquisition professionals make the decisions up-front with the operators. The investments are accomplished via comprehensive and coordinated education systems, training evolutions, experiments, and laboratories through which the team will obtain the necessary knowledge, understanding, and abilities.

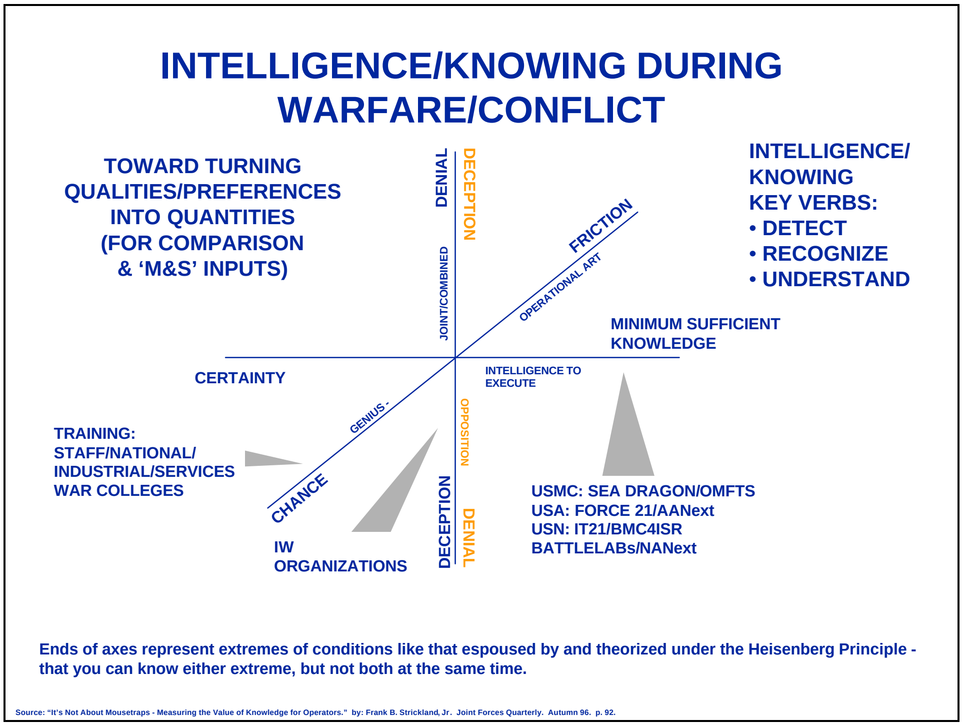


Figure 3. Intelligence / Knowing During Warfare / Conflict

Training and investment in the team, increases its ability to discuss, analyze, and reason. The team will be armed with understanding to deal with uncertainty and to exchange ideas with members of the other services and U.S. allies. This can promote the development of an understanding of needs, intents, and outcomes; all of which will come together when operational missions are seamlessly executed and the intended outcome achieved. Through exercises and experiments (including the participation of operators, maintainers, producers, vendors, etc.) mission capabilities and limitations become clearer to all team members. The opportunity exists for the team of operators to be ready to employ the mission capabilities of the equipment and components upon delivery from the production line. The opportunity is present for TTPs and combat system components to come together at the correct time. Providing the right training at the right time, just-in-time training, fully integrated with the systems engineering process, providing mission capabilities packages on a 'plug-and-play' basis, supports rapid, appropriate response to threats. This is mission success, delivering as promised, a useful Program Manager metric.

Opportunities exist to assist in identifying the dangers and reducing their risks, and thus, contribute to the safe passage through the fog of conflict and areas of restricted maneuvering at any speed even in the face of uncertain conditions.

Mission Success ???

There seems to be some progress on the manufacturing side for improving the introduction rate of the system-of-systems components. The announcement to continue using MIL-SPECs, only by exception, is a major initiative of acquisition reform, with the objective of accelerating acquisition and introduction of new equipment and capabilities. Given that the Department of Defense (DoD) no longer drives most key technologies and the fact that it takes eleven to thirteen years on an average to field a major weapon system, technological rate of change presents a formidable challenge to any program manager. This fosters dependence on commercial-off-the-shelf (COTS) components from all sources.

While COTS products can support the kernel of mission capabilities, the personnel supporting the TTPs, CONOPs, interoperability, and other logistics do not always receive the same financial resources, or may be more vulnerable to apportioned resources reductions. When confronted by resource reductions, it is a recognized option to preserve the mission capability kernel by reducing the logistics resource allocation, but whose mission success criteria?

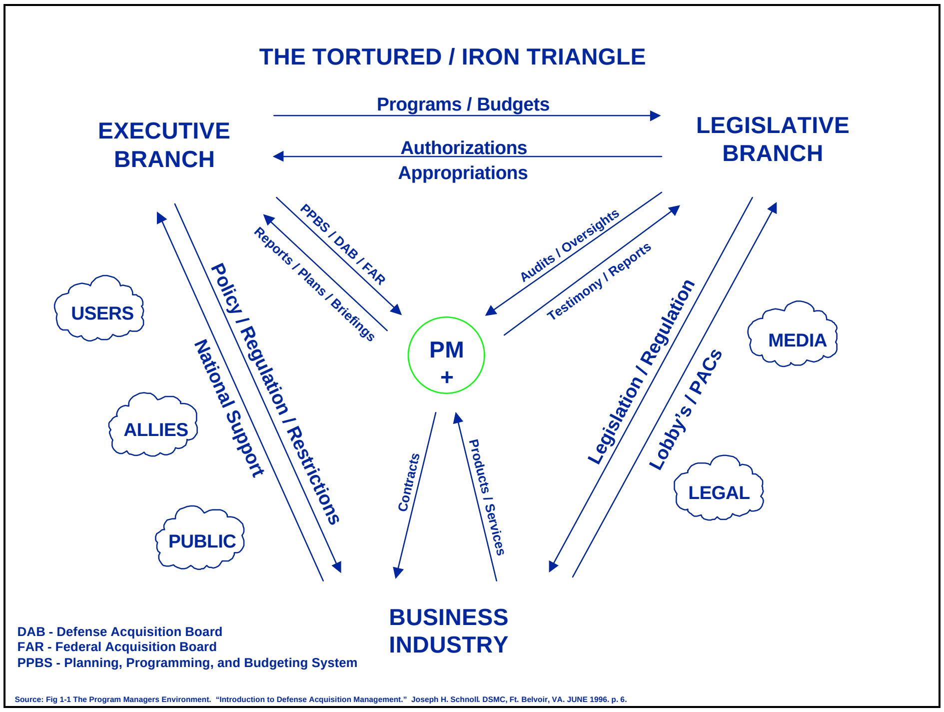


Figure 4. The Tortured / Iron Triangle

The example noted above emphasizes the complex and challenging roll the Program Manager must fill while quite literally sailing in confused seas, or trying to follow the confusing directions of many navigators (commanders) in restricted waters as depicted in Figure 4. To be fair, it places an additional burden and risk on program managers and their resources. Resource sponsors and senior leadership should recognize this burden and provide additional support balancing horizontal and vertical resource allocations.

Improvements in the hardware side of the mission capabilities packages for combatant commanders must also address personnel and TTPs. If the system engineering product is to become an operational mission capability, it must be developed in an operational engineering environment through the team of operators and acquisition professionals. Current practices must be strengthened and enhanced to further accelerate the development of operations, training, doctrine, and interoperability of the system-of-systems. An opportunity exists for marrying the promised efficiency initiatives of acquisition reform and revolution in business affairs with the strength and computing power of the evolving NII/DII.

This approach may be described as a modification of the spiral, evolutionary production of software. This represents reducing the number of cycles and equates to the expected outcome of the operational engineering environment – accelerating introduction of mission capabilities. Co-evolution is an essential element of the Operational Engineering of our systems. Early involvement of the end user war fighters will enable them to test emerging capabilities through war games, experiments, and exercises. Early operator and user involvement will provide a receptive engineering and acquisition community with the critical feedback that can influence designs and architecture early enough to reduce the possibility of subsequent costly changes, while instilling mutual trust and understanding in both communities.

If the Mission Area Analysis determines there is no TTP solution, the traditional step is to work out the long acquisition plan for the hardware, computer programs, and all the other elements of system life cycle support - including logistics support. As stated previously, war fighters continued involvement is key to the engineering and acquisition community for the operations, training, doctrine, and interoperability aspects of weapons systems development. Admiral Spruance noted, “A sound logistic plan is the foundation upon which a war operation should be based. If the necessary minimum of logistics support cannot be given . . . the operation may fail, or at best be only partially successful.” [NDP-4, 1995]

The designers, engineers, and sailors must knowledgeably and collegially approach weapons systems operational engineering from the warriors’ perspective. The systems must be engineered as though our lives depended upon them! For all logistics support planned and delivered late does not support promised mission capabilities packages. That is not serving the customer, it is NOT MISSION SUCCESS! Failure to address logistics, in fact, compromises mission success.

Toward Mission Success! (Safe Passage)

Are we adequately utilizing the investments in the DII and NII? The Navy’s distributed engineering plant (DEP) and the developing joint M&S infrastructure share many components. Their products and functionality are different, while providing complimentary capabilities to their users. (See Figure 5, for a partial representation of this modeling continuum.) Can they be further leveraged to assist TTP development for the war fighters, who can also go on-line? This interaction can assist in determining the detailed structure of mission capability packages and their contributing factors to overall assigned missions. That development provided on line would support the underlying foundations for

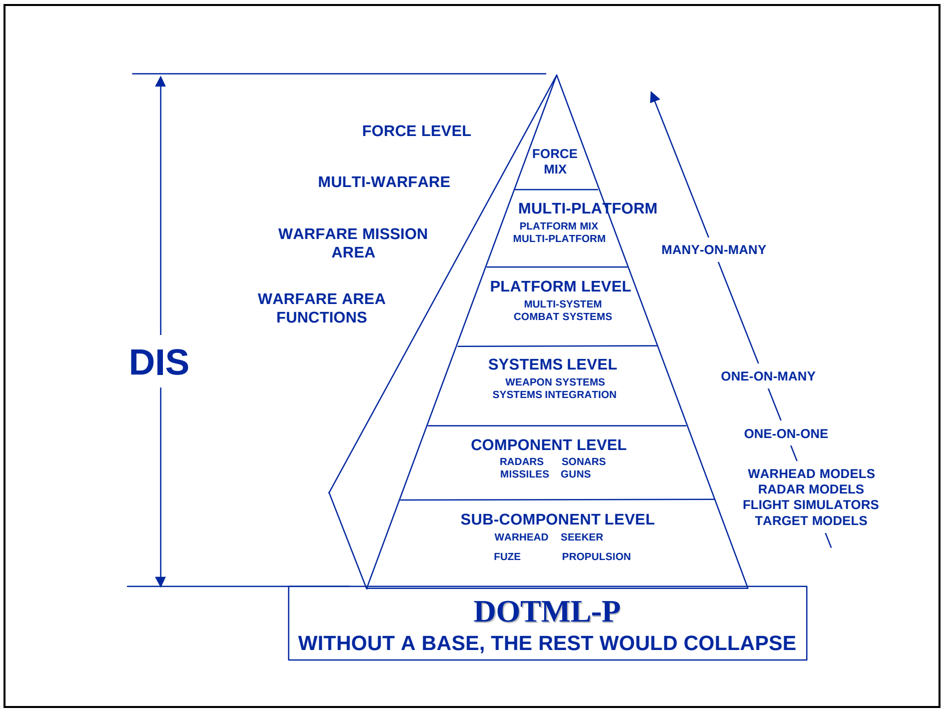


Figure 5. Distributed Interaction Simulation Continuum

overall TTP development for different war fighter levels. Thus an alignment of STRATEGIC through TACTICAL direction would lead to the development of VECTORED courses and speeds which support all the levels of strategic planning through tactic employment, and allow knowledge and understanding to ease the uncertainty of the fog of conflict. This is akin to the realization of Sun Tzu's observation [Griffith, 1971]: "If you know the enemy and know yourself, you need not fear the result of a hundred battles. When you are ignorant of the enemy, but know yourself, your chances of winning and losing are equal. If ignorant of both your enemy and yourself, you are certain in every battle to be in peril." This understanding supports MISSION SUCCESS.

In Desert Shield and Desert Storm, highly trained war fighters, using mature and new systems, including precision guided munitions, created the success. [Carafano, 1998] This personnel development foundation was recently emphasized by the President of the Naval War College, Vice Admiral A. K. Cebrowski [1999]**,** "Give us a student for 10-months, and he/she will be make better decisions for the next 15-20 years!" Admiral Reason [1998] likewise advised that supporting the sailor inputs would provide the edge with ideas and solutions through training and testing initiatives, for the sailor is on the front line.

The citations point to top to bottom investment. The NII/DII can support this area via a near real-time analysis capability (a T-JAWC) to the front line team of operators. The key point, however, is that the team of operators are the ultimate customer of the Program Manager's deliverables. They are the users who will either enjoy the benefits or suffer the consequences of the program's success or failure. The desired outcome is maximum effectiveness for minimum resource expenditure.

Operational Engineering (Piloting Assistance) – *The The Winds of Acquisition Reform*

Colin Clark [1999] noted that Under Secretary of Defense for Acquisition and Technology (USD(A&T), Dr. Jacques Gansler in February 1999, directed that all new weapon systems be produced in half the average time. He has also directed that half of the new weapon systems must achieve their cost goals. Quoting Mr. Stan Solloway, Dr. Gansler's deputy for acquisition reform, "Our principal intent is to take action to reduce the time it takes the department to field new systems, what we call cycle time, while limiting the cost of those systems." [Clark, 1999] Even with policy changes to implement this reduction in cycle time, the quest to accelerate delivery of systems will be a great challenge to keep on course. Although the acquisition community is officially encouraged to take calculated risks, significant factors beyond a Program Manager's sphere of control can increase risk, continually challenge accelerating delivery of systems, and far too often cause delivery schedules to "slip to the right" and costs to increase. At times, the challenges are of such a magnitude that program re-baselining is warranted.

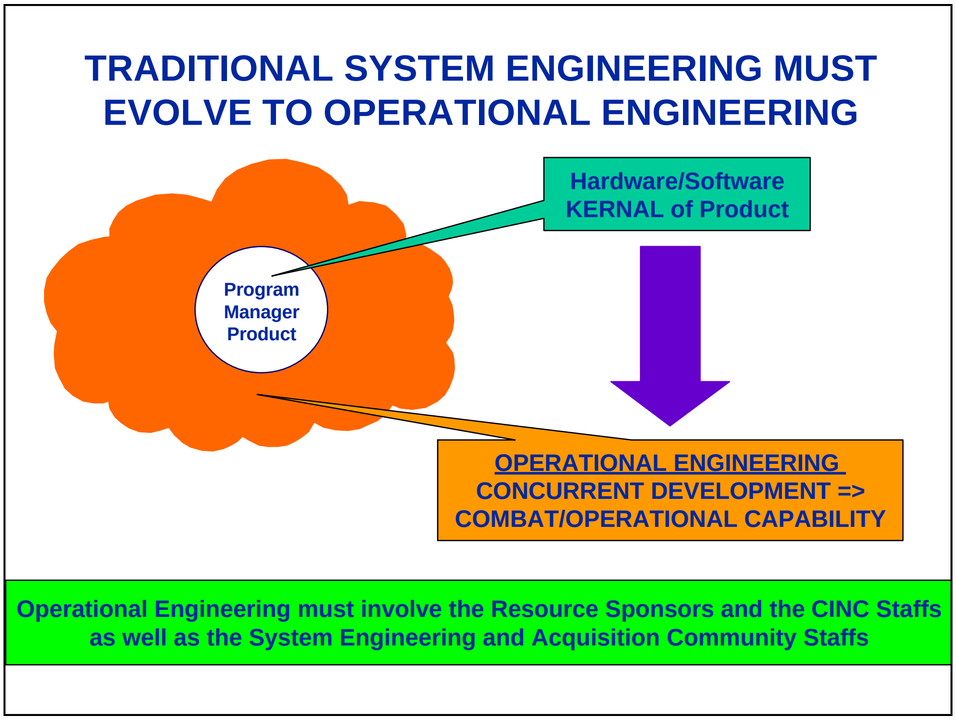


Figure 6. From System Engineering to Operational Engineering

System delivery, however, while serving as the critical hard kernel or component of a new or improved war fighting capability, does not in and of itself equate to fielding an operational war fighting capability. Much as system engineering term "combat system" evolved from an original focus on the hardware and computer programs to encompass the operators and maintainers of the systems, accelerating the delivery of systems also needs to be viewed in this broader context. Operational Engineering, which encompasses system engineering, is a broader discipline through which operational war fighting capability. Operational Engineering is not a radical departure from the existing system engineering process, rather it is a logical evolution as depicted in Figure 6.

System engineering's principal product is delivering the hard, *substantial*, physical core of a combat capability that satisfies the defined requirements. Absent this real, tangible, measurable core, it is far too easy to slide into the realm of science fair or even science fiction. Classic system engineering, however, is no longer enough. This is especially true given the accelerating rate of technological evolution and the speed of moving new technologies to market. As Japan proved to the U.S. in the 1970s and 1980s, it was not which side first engineered a new technology, rather it was being the first to get a usable, quality product in sufficient quantity to market. Product fielding was a key ingredient of their economic success. Similarly, from a combat capability perspective, it is not which side achieves system engineering success first, rather it is which side is able to first field a new or enhanced operational war fighting capability in sufficient numbers to gain a war fighting advantage. Confederate General Nathan Bedford Forrest, when asked about the key to his many victories stated " I get there first with the most." Operational engineering acknowledges the wisdom in these words. [Ward, 1990]

Operational engineering recognizes the principle of Cost as an Independent Variable (CAIV.) Cost is a driving factor in acquiring the sufficient numbers of weapons and systems that are essential to achieving operational superiority, and even supremacy, and to sustaining that advantage for the necessary duration.

A Program Manager's primary objective is for their systems to satisfy the approved Operational Requirements Document (ORD) threshold criteria within given resource, time constraints, and top level requirements (TLR). Attainment of objective criteria is balanced against Cost As an Independent Variable (CAIV) parameters. Satisfaction of the Key Performance Parameters (KPPs) is the metric against which threshold and objective criteria success is measured. This includes the recent KPP interoperability requirement for those major systems that must operate in a broader system-of-systems.

Given the burden of embracing calculated risks and laboring under constrained, often fluctuating resource levels, and aggressive schedules, the less a Program Manager has to deliver, the more opportunity for program success. Insularity from external influences offers some definite short-term advantages when viewed from this perspective. The concern is that these pressures can encourage the current system engineering toward service specific optimization, individual service interpretation of joint standards, service specific tools sets, and service based configuration control. Overly insular system engineering may lead to stovepiped solutions, which work fine independently but can not communicate seamlessly from a system-of-systems or family-of-systems perspective. The important point here is to better understand the joint war fighting requirements and to ensure that the system engineering community addresses these requirements up front.

It is essential that systems engineering include from program initiation how individual systems will operate with and contribute to the broader system-of-systems or family-of- systems. DoD senior acquisition leadership recognizes this challenge. Clark [1999] notes that Dr. Jacques Gansler's, 14 July 1999 memorandum "mandates that a weapon's ability to work well with allies' weapons is now a requirement." To implement this policy, senior DoD leadership needs to institute and provide tangible support for a disciplined engineering acquisition process that delivers weapons systems which incorporate the necessary degree of joint (and even allied) interoperability to the war fighters. System engineering and acquisition life cycle strategy must address the war fighters need to have family-of-systems interoperability. This is especially true with the Major Defense Acquisition Programs. Further, while policy pronouncements and oversight are a good start, sufficient and timely resource allocation are absolutely essential. Absent that support, the above policy becomes another unfunded mandate.

A key goal is to reduce, and eliminate if possible, those actions which degrade system employment effectiveness. In essence, Operational Engineering seeks to significantly encourage significantly greater external, joint war fighter feedback into the system engineering and acquisition process, particularly in the early acquisition phases, but also throughout the entire system life cycle. The old adage of 'train the way you intend to fight' needs to be expanded to include '. . . and engineer the systems for the fight.'

The Concept of Operational Engineering

U.S. forces are increasingly expected to operate and fight in a joint, and probably coalition, environment. This requires knowledge and understanding of the other services doctrine and TTPs, as well as the nuances of their service culture if we are to operate effectively together. Naval war fighting capabilities must have the requisite degree of joint interoperability. In any Major Theater of War (MTW), there will be significant reliance upon allies and coalition partners. Many of these allies and coalition partners may not have the resources to acquire and maintain interoperability with US forces. This was highlighted during the recent Noble Anvil operations in Kosovo. [USACOM J6, 1999] Such joint and coalition military operations not only have political and economic dimensions, they also have implications for how the Naval community engineers and acquires systems, trains its forces, and the extent to which the community designs in and implements force interoperability. Solutions will need to be crafted that address serious impediments such as common technical standards, data release, standardized terminology, limitations with regard to operational control and discipline, and even different national acceptances of international laws and protocols.

The recent stand-up of Joint Forces Command demonstrates leadership's recognition of these challenges in executing U.S. National Military Strategy. Seffers [1999] reports "The Joint Forces Command, formerly known as Atlantic Command, was renamed October 7 and given a new mission to define strategies, doctrine and tactics that improve the ability of the military services to work together on the battlefield." Further, Commander, Joint Forces Command, Admiral Gehman notes that, "To meet the challenges of the 21st century . . . we are going to have to change the way we address interoperability and joint operations." [Seffers, 1999] It is the authors opinion that to perform this mission, Joint Forces Command will likely need to strengthen the linkage between the war fighters and the engineering and acquisition communities that arm the war fighters. In this context the Navy needs to evolve system engineering as the critical tangible kernel into the broader concept of Operational Engineering.

Navy Operational Engineering will build upon an already strong system engineering heritage and foundation. Navy Operational Engineering must have a greatly expanded external outlook and will require even closer cooperation and coordination of all interested parties than does system engineering. Stakeholders include not only the system engineering and acquisition community; fleet war fighters; and, the test and evaluation community; but also, the other half of the Naval team, the Marine Corps; our sister services; the Surface Warfare Development Group; the Maritime Battle Center; and key Joint constituencies, especially those involving experimentation and joint interoperability. In the broadest sense, allies and potential coalition partners are also included.

This expanded group of stakeholders influences how current and emerging programs are managed and resourced. Involvement is predicated upon the availability, and development, of knowledgeable liaison personnel. This is likely to be an additional burden, for understanding the other services' visions and master plans directions and implications for Naval forces will be critical. Conversely, there is a need to keep the other services informed about Naval efforts and intentions. There are a number of vehicles or forums for sharing this information throughout the key stakeholders' constituencies. Foremost among these are joint war games, exercises, and experiments sponsored by joint commands and the individual services; some of which include allies and potential coalition partners participation.

Different events have different purposes. Exercises might be Tier II for staff training or Tier III for Field Exercises. Experimentation, on the other hand, allows testing of new ideas and technologies when all the bugs are not worked out. In theory, such experimentation is a failure tolerant venue and provides valuable insights into what is worth pursuing and what is not. At times multiple smaller exercises, experiments, and events can be grouped together and mutual leveraging occur such as the upcoming Joint Forces Command sponsored Millennium Challenge 2000 exercise.

Each of the Unified CINC is a different audience that crafts its exercises and war games to suit their specific needs, i.e., to test their Operations Plans (OPLANS) and Concept Plans (CONPLANS). Program Manager's pro-active involvement in their war games, experiments and exercises can garner the CINCs support, influence their Integrated Priorities Lists (IPLs), and even impact the CJCS Chairman's Program Assessment. Although this has always been true, it has become more important since the Goldwater-Nichols Act of 1986 delegated significantly greater power to the CINCs.

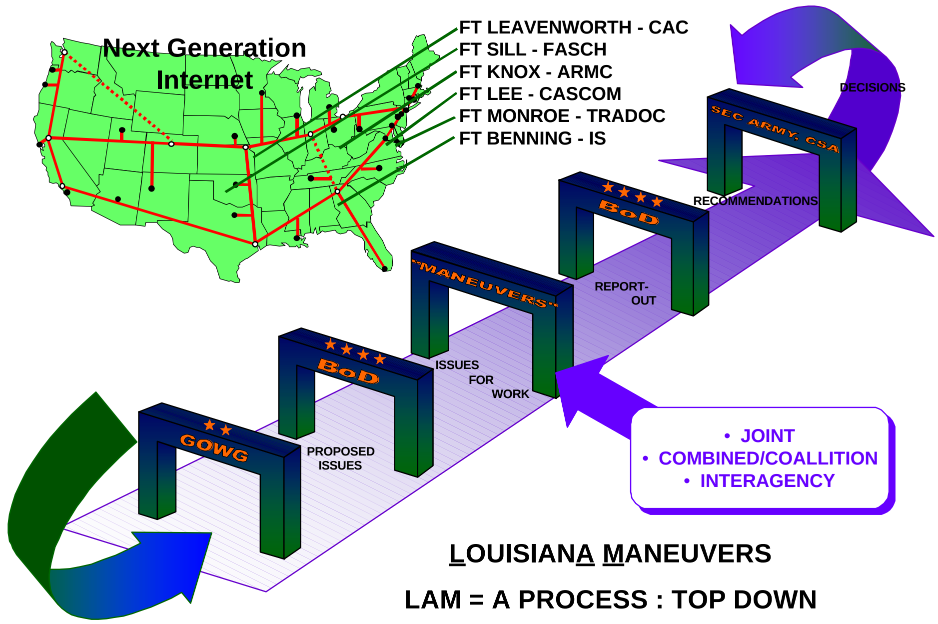
These CINC sponsored events are the most visible forums in which Navy can demonstrate current and emerging capabilities and where the engineering and acquisition community can directly engage in the development of CONOPS, tactics, and inter-operability. It is where current and emerging capabilities can be demonstrated and tested with the CINCs OPLANS. Failure to participate in those events with knowledgeable personnel can result in a vacuum where Navy capabilities can be ignored, misunderstood, or even misrepresented. In addition to building a broad based understanding of Navy capabilities within all the key CINCs and their staffs, CINCs' concerns can be relayed back to the acquisition community. Another benefit includes the ability to perform side excursions to examine system capabilities in both symmetric and asymmetric war fighting operations. This permits assumptions to be critically challenged and evaluated with feedback into the Operational Engineering process.

Given the nature of their missions, forward deployed CINCs have to emphasize current and near term capabilities of the forces that deploy in their theater. Time constraints impact issue resolution and generally emphasize procedural work arounds or quick technical fixes for urgent problems. While Joint Forces Command addresses current and near term capabilities, its role as a major force provider to the forward deployed CINCs, makes it the principle proponent for all CINCs in addressing mid- and long-term issues where solutions are more likely to involve engineering and acquisition. Supporting such efforts, Joint Forces Command already has unique infrastructure including the Joint Battle Center, the Joint War Fighting Center, the Joint Training Analysis and Simulation Center, and proximity to the services' acquisition, engineering, and logistics communities and facilities.

Joint Forces Command may well upgrade these existing facilities. Investments may also be made in additional infrastructure such as the proposed Joint Distributed Engineering Plant (JDEP) with its potential for evaluating the interoperability of joint forces slated to arrive in CINC theaters as part of each OPLANs Time Phased Force Deployment List. Such a tool can be used in the OPLAN validation process as well as to establish a baseline from which near, mid and long term solutions can be planned, reflected in the CINCs IPL, executed, and subsequently re-tested. Under Joint Forces Command auspices, the potential exists for the individual CINC IPLs to be grouped under a single Joint IPL or Joint Requirements List. While possibly diluting an individual CINC's priorities, the overall effect may be to strengthen their collective input and bolster the annual Chairman's Program Assessment. Additionally, individual services' system engineering and acquisition communities may receive more focused and consistent guidance.

From a broader perspective, event participation affords Navy an opportunity to "strut our stuff" to the members of the Joint Services community and allies who come to these events. This in turn fosters vital data and information exchange, which is the foundation to improved interaction with the other services' current and emerging capabilities. It is a critical step in resolving joint interoperability issues and to Navy success as a service provider to the war fighting CINCs. Event participation also provides exposure to the Navy War College's intellectual and academic communities that are important to defining future roles, missions, and force structures. At the U.S. Air Force Chief of Staff sponsored, Global Engagement IV in October 1999, Navy's current and emerging capabilities were authoritatively portrayed and were reflected in the out briefs given to the Secretary of Air Force and the Chief of Staff of the Air Force.

Participation is useful from a "marketing and education" standpoint as well as being an integral part of system engineering. Participation extends beyond that to supporting the fielding of operational capability by contributing to the concurrent development of CONOPS, tactics, and interoperability, and to the reduction of the timelines to field those capabilities. (An example is shown in Figure 7 –Louisiana Maneuvers –of the feedback loop similar to that of Operational Engineering, though at a higher level. [Wilson, 1996] & [Leibovich, 1999]) This interaction or bridge between the war fighters, strategists, and the engineering acquisition community is a fundamental component of Operational Engineering. It keeps the end users' needs in the forefront, gives the strategists a firm base of reality to work from, and allows the war fighters to influence the emerging systems that they soon will depend on for successful accomplishment of their assigned missions.



Source: Derived from Fig 1 "Battle Labs: What are They, Where are They Going?" John R. Wilson, Jr. Acquisition Review Quarterly. DSMC, Ft. Belvoir, VA. Winter 1996. P. 65. "No Speed Limits On the New Infobahn - Universities, Businesses Launch Internet2." Mark Leibovich. The Washington Post. February 24, 1999. P. E1 & E1o.

Figure 7. Testing the Ideas and Using the Network

Finally, event participation is a two way street. Navy's on-going role in the system engineering development of the Joint Interface Control Officer (JICO) came about through participation in the Roving Sands and All Services Combat Identification Evaluation and Testing (ASCIET) exercise series since 1996. JICO cells have subsequently been deployed during Noble Anvil operations in Kosovo and are active in the on-going operations against Iraq. Another example is the Navy's Area Air Defense Commander (AADC) capability under the program management of PMS 467 within PEO TSC. (Figure 8 shows the intended reversal in levels of initial work and analysis of options offered by the AADC capability.) This program traces its roots to Navy involvement in Roving Sands 95 and 96 where Navy was exposed to the Army's developing capabilities now resident in the 32nd and 263rd Army Air and Missile Defense Commands.

Accomplishing Operational Engineering

As previously outlined, Operational Engineering embraces a broader perspective than system engineering. While including "cradle to grave" system engineering, Operational Engineering adds emphasis on the concurrent or co-evolution of CONOPs, TTPs, training, and joint interoperability. These are the elements that transform a kernal system engineering capability into an operational war fighting capability. Overlaying Operational Engineering throughout the

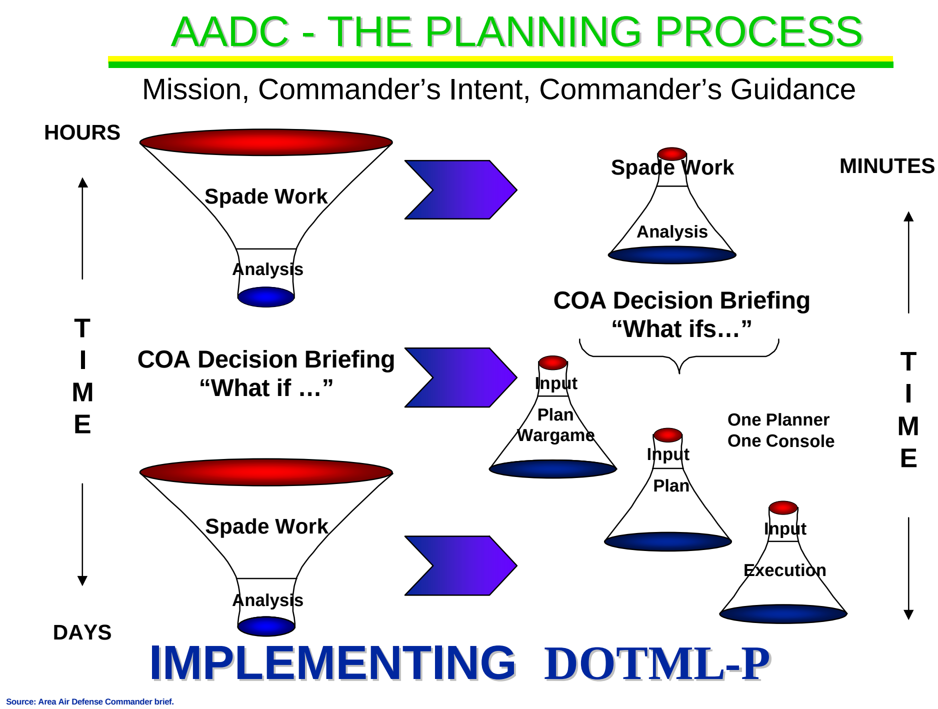


Figure 8. AADC - Helping Accelerate the Decision Cycle

proven system engineering process results in critical insights being gained early when changes can be made more cost effectively.

Based on the foregoing, the authors believe Operational Engineering has at least the following three goals:

(1) provide greater early interaction between the system engineering and acquisition community, and the principal customer, the war fighters, to ensure that systems will satisfy known, valid requirements;

(2) concurrently engineer system interoperability with other existing and emerging systems which the system will have to operate to ensure a seamless mesh within the joint war (and coalition) fighting environment; and,

(3) accelerate system initial operational capability (IOC).

While there are political and economic costs associated with increased involvement with allies and potential coalition partners the Operational Engineering environment offers greater opportunities for participation than currently exist under bilateral and multi-national programs, and the Foreign Comparative Testing Program. Gains may include systems where an ally's technology, engineering, or manufacturing processes are superior to those in the U.S. Increased interaction with other countries' armed forces during peace will likely improve those forces interoperability during conflicts. Further, increased interaction can provide U.S. forces with significantly valuable and different perspectives on tactics and CONOPs. This is especially true when operating with those allies possessing high quality armed forces, because of severe resource constraints, compensated with innovative tactical concepts, training, and a thorough understanding of their likely areas of operation. Operating alongside such professional allied forces can drive home the valuable lesson that although technological superiority confers significant tactical advantage, it is only when technological superiority is wielded by trained and knowledgeable personnel executing well thought out doctrine that war fighting superiority and supremacy can be reliably achieved.

The Operational Engineering goals may require infrastructure investments or the innovative use of existing infrastructure. An excellent example of innovative use is NSWC Dahlgren's distributed M&S capability originally designed to support Navy participation in joint war games and first used in Roving Sands 96. Operating in conjunction with the ATRC's superb training facilities, this capability is the core of the DEP that is now used to test Carrier Battle Group pre-deployment interoperability and grant certification. It is a highly leveraged and utilized resource. The NSWC and ATRC team has helped develop and refine CONOPs, TTPs, and interoperability in the initial absence of a full suite of locally available tactical systems. As tactical systems, such as Linebacker 5.L.X, become available, they have been incorporated into exercises, events, and training. Resource management issues can help govern configuration choices for specific events, balancing desired fidelity level against resource availability and assessed return on investment.

The most realistic location to perform Operational Engineering is on units with the actual crew using their own systems. Significant challenges exist to doing this however. Unit and crew availability, Personnel Tempo (PERSTEMPO) and Operations Tempo (OPSTEMPO) limitations associated with deployment cycles, cost, and the fact that developing systems and prototypes are installed only on a limited number of units, has lead to the development, engineering, and use of other innovative, acceptable solutions, including the use of constructive and virtual simulations.

For example, a good alternative when AEGIS ships are unavailable, is ATRC. Specifically, because ATRC's primary mission is to train Prospective Commanding and Executive Officers, along with Fire Controlmen for their duties aboard AEGIS ships. Theater Air and Missile Defense is strongly emphasized. ATRC's resident training infrastructure, including several complete Combat Information Centers (CICs), is integral to accomplishing this primary mission. Training, in fact, is a crucial element of Operational Engineering.

Training can expose systems, including the personnel part of the systems, to a wide spectrum of symmetric and asymmetric scenarios as part of the Operational Engineering process. Facilities such as ATRC train war fighters in the full capabilities and limitations of the systems that the system engineering and acquisition community provides. The importance of training within Operational Engineering can be seen in Field Marshal Erich Von Manstein's [1982] description of a key Hitler failure. Von Manstein believed that Hitler "over rated technical expedients . . . (What Hitler) forgot was the amount of training and skill required to render a new weapon fully effective. Once the new weapon reached the front, he was content. It did not worry him whether the units concerned had mastered them or not, or whether a weapon had even been tested under combat conditions." Likewise, the importance of training is cited by Carafano [1998].

ATRC's CIC laboratories and training facilities allow battle group staffs and ship tactical teams to participate remotely in CINC exercises using as much real tactical hardware as possible. Current tactical software is used whenever feasible. New capabilities, such as Linebacker, are included in exercises, even when the small number of ships with this operational capability are unavailable. Simulations such as Multi-Warfare Assessment Requirements System (MARS) allow portrayal of future capabilities. Simulations also provide a robust back-up capability should problems arise with the real tactical equipment, as occurred during Roving Sands 99. Constructive simulations, using MARS, allow creation of virtual ships to participate alongside sailors manning ATRC's tactical consoles. An environment populated this way supports battle group staff training in the exercise of command over several battle force and joint units, without expending scarce flight or steaming hours. Battle group staffs operating from ATRC have acted as Joint AADC and Maritime Regional Air Defense Commanders.

Each of the above operational engineering environments has its advantages and disadvantages. Ship crews operating their own equipment reflects operational reality and offers the most realistic training environment. Ship availability, conflicting demands, and the inability to train on systems not yet delivered, limit this option. School house constructive simulations environments, especially those intimately linked with the engineering community, such as ATRC with its NSWC Dahlgren nexus, are a superb alternative. School houses allow personnel to operate the same equipment that is aboard their ships while sharing the advantage of M&S because scenarios can be played back and repeated to enhance training. M&S of medium fidelity virtual environments is usually the least costly and can portray advanced systems prior to the physical availability of those systems. Rapid technological advances in visualization, increased computational power, improved communications connectivity, and reduced cost continue to make this a more attractive option but depends upon up front investment. Optimal value, however, can happen when live ships interact with constructive and virtual simulations, in a carefully planned and structured environment. This was demonstrated during Theater Missile Defense Initiative 98. [FBE-Charlie Quicklook Report, 1998] This exercise included the Navy's AADC prototype capability at the Johns' Hopkins University Applied Physics Laboratory. Commander, Cruiser Destroyer Group Two, serving as the Area Air Defense Commander, concluded that integrating real world C3 with live and simulation forces, in a Field Training exercise, allowed U.S. Atlantic Command to take a major step forward to integrating joint forces. (NOTE: Since that test, U.S. Atlantic Command has been renamed and refocused as Joint Forces Command.)

Mulholland [1999] noted the "Defense Science Board task force study *Advanced Modeling and Simulation for Analyzing Combat Concepts in the 21st Century* . . . finds that those formulating Joint Vision 2010 are not taking advantage of available M&S tools. The report stated 'We found only rudimentary application of M&S toward exploring new (combat) and operational concepts'." In counterpoint, PEO TSC's extensive use of MARS and other simulations in twenty CINC and service exercises and events during Fiscal Year 2000 represents a strong commitment to answering such concerns.

The key behind obtaining valid results through M&S is the balanced mix of simulations with known capabilities and limitations, valid data, and operators and analysts who are knowledgeable of both the simulation AND the current and emerging systems that are being represented. The danger of generating invalid or misconstrued results absent any of these three key elements is significant.

In addition to training value, facilities such as NSWC and ATRC provide a joint and service forum where insights can be derived and fed back into the Operational Engineering process. Validation and refinement of operational knowledge and procedures is central to achieving practical solutions concurrent with system engineering. The key is to derive and apply the operational lessons learned within the current customary feedback cycle time of the system engineering process.

Operational Engineering is a life cycle process that has the potential to make a major contribution toward maintaining full spectrum dominance through the parallel acceleration and delivery of operational war fighting capabilities alongside traditional system engineering and acquisition. This is process innovation excellence. By expediting development of war fighter confidence and competence with emerging systems, continued tactical superiority can be maintained by U.S. forces staying inside potential enemies Observe, Orient, Decide, and Act (OODA) cycle. The potential exists to give U.S. war fighters a greatly improved ability to overcome that which is “strange and unexpected” and to thrive in an environment where the fog of war normally would have constrained operations. [Potter, 1986]

The objective is employing U.S. mission capabilities to negate enemy mission capabilities with a minimum expenditure of material resources. This objective might be met by marrying precision guided or smart munitions with skilled and knowledgeable war fighters to produce decisive effects. This is the ultimate desired outcome from Operational Engineering as embodied in a Tactical-JWAC, positioned in the structure of capabilities shown in Figure 9. Providing support

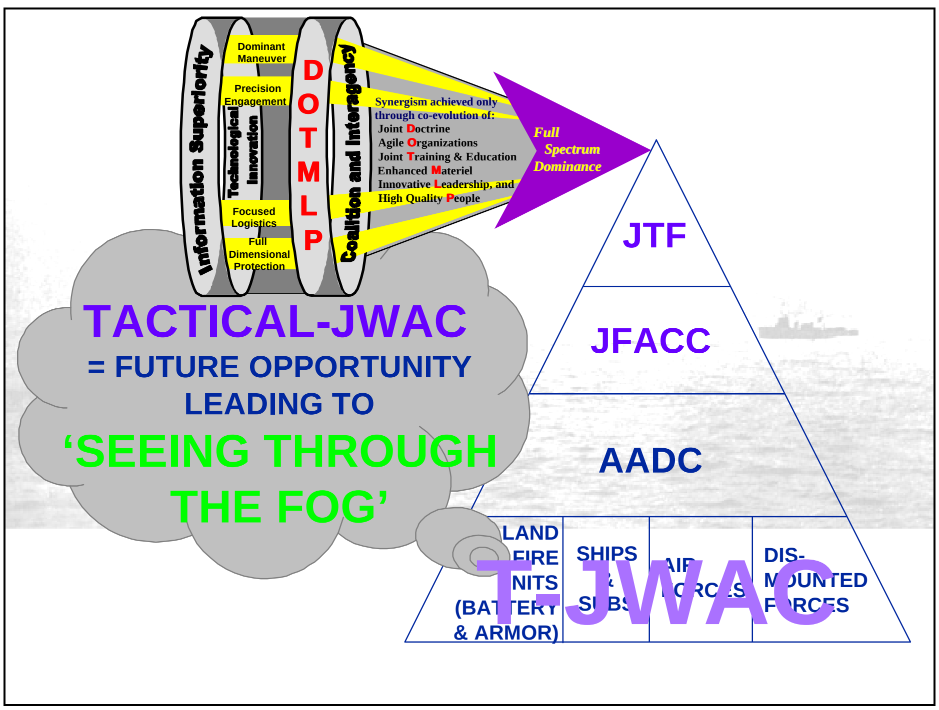


Figure 9. The Future Opportunity - Tactical-JWAC

to Land Fire Units (Battery & Armor); Ships & Subs; Air Forces; and, Dismounted Forces for near real time, on-line analysis of military engagement options.

For example, a Navy combatant platform's size, compounded with multi-mission design tradeoffs, limits its ordnance load out. This limitation causes balancing load out against desired decisive effects. To get these decisive effects calls for the use of brilliant effects based targeting and decision aids from all services. Since forward presence will continue to place Naval platforms in the forefront for national military strategy employment, there is the need to meld Naval capabilities with the other services and allies. Thus testing the concepts of employment within a system-of-systems and an interoperable family-of-systems Operational Engineering environment has great appeal.

Current DoD requirements to engage in two near simultaneous Major Theaters of War (MTW) will severely strain the finite precision guided munitions inventory and other low quantity, high value systems. This is particularly true if re-directing these assets from the first theater to the second is required. The key here is, again, the philosophy: MAXIMUM EFFECTIVE – MINIMUM USE OF RESOURCES, along with the effects based acquisition, engineering, and operations that enable this to be implemented by the war fighters, using Operational Engineering.

To maximize return on investment, Operational Engineering must also continuously evaluate and improve the effectiveness of aging systems as operational condition and resources warrant. Operational Engineering must address the full spectrum of operations (MTW to Operations Other Than War (OOTW)), including an increased emphasis on logistics beyond that in the current system engineering life cycle process. Operational Engineering must not only embrace the new concept of 'effects based operations,' it must take into account the underlying effects based engineering, acquisition, and logistics. Logistics must not only address readiness, but also the ability to sustain front-line U.S. operational war fighting capability, especially during times of high ordnance expenditure. The right kinds of on-call, surge firepower capacity is a critical factor for U.S. forces fighting a war of maneuver and firepower. Absent this, U.S. forces run a greater risk of the higher casualties associated with attrition warfare.

Collegial communication between the war fighter and the engineering and acquisition community is a two way street. One direction provides the system engineering feedback, the other provides emerging system performance information. Together both permit the concurrent development of those elements that transform a system into an operational mission capability.

Much as system engineering has a principle objective of reducing engineering and acquisition risk, Operational Engineering must have a principle objective of reducing operational risk. Operational Engineering must involve the resources sponsors (CNO Staff); the system engineering, logistics, and acquisition communities; as well as the war fighters. Ultimately, Operational Engineering's principle objective is to provide a decisive war fighting edge by accelerating delivery of war fighting capabilities to the war fighters who are ready to operate and employ new systems upon arrival.

SUMMARY AND CONCLUSION (MASTER'S LISCENSE)

Operational Engineering's goal is aptly embodied in the martial arts dojo aphorism, 'MAXIMUM EFFECINCY – MINIMUM EFFORT.' A national security (war fighting) corollary is, 'MAXIMUM EFFECTIVENESS –MINIMUM USE OF RESOURCES'.

The authors' specific recommendations are in two components:

(a) Initiate integrated co-evolutionary development and testing of doctrine and training via the concerted and coordinated use of the battle laboratories, evolving DEP, innovative reality grounded joint services exercises, joint services experiments, and M&S characterized by knowledgeable and collegial efforts. This has four sub-components:
   - To support knowledgeable war fighter development, and co-evolutionary development and testing of CONCPS, TTPs, and doctrine, test the concept of an online, near real-time Tactical Joint Warfighting Analysis Center (T-JWAC) via joint and service war games, experiments, and exercises. Perform a thorough and critical analysis of results for improvements and total learning. After testing, a proposed objective might be to evolve from an initial reach back capability and ultimately a portable capability when no reach back is available.
   - To support the early evaluation of mission capability contributions in the anticipated operating environments for the Combatant Commanders' assigned missions, require the inclusion of doctrine, TTP development, and interoperability criteria into the early milestone (0, 1, and 2) decision process. This is in addition to the examination of different non-hardware operational solutions performed during the initial MAA which determines whether the solution can be done with procedure and doctrine changes only, or requires material changes.
   - To evaluate the large picture impact of promised capabilities delivery in the international operating environment, which includes military, economic, and political interactions, transition to 'utility outcomes model' discussed by de Mesquitea [1997], for evaluation of system TTPs and doctrine against the assigned Combatant Commander assigned missions the system-of-systems, family-of-systems components.
   - To monitor the Program Managers' delivery of promised capabilities and contribution to MISSION SUCCESS, initiate a reporting requirement for evaluation and assessment of Program Mangers' performance from their customers, the Combatant Commanders, via concurrent FITREP input based on capabilities provided, compared to capabilities promised.

(b) To develop individuals' understanding of the larger picture and awareness of the operating environment that surrounds day-to-day operations, use Joint Professional Military Education certification as an evaluation item for selected mid-level managers and leaders when considering professional development and position selection. This has been implemented for Flag Officers. This certification is available in developmental programs (like Defense Leadership and Management Program (DLAMP)), and to military and civilian members of the work force through the Services' War Colleges and the National Defense University.

These recommendations go to the heart of Operational Engineering. Implementation of the recommendations will not be easy and will be controversial. Still, honest discussion and critical evaluation of these recommendations may stimulate the evolution of the current system engineering process and improve U.S. operational war fighting capabilities.

There are costs associated with exercises, battle labs, experiments, and TTP development. What is often neglected is distilling the results from these events and timely re-investment of lessons learned into a systems engineering environment let alone the proposed Operational Engineering environment. The costs of these efforts are appropriate costs for the services to bear and budget, as well as for programs to pay when working through early acquisition phases. In some cases, particularly those impacting Battle Management Command, Control, Communications, Connectivity, and Intelligence (BMC4I), resource provision and sponsorship are more appropriately a joint responsibility.

The rate of change in information technology; the frailty of the military peer superpower; and the emergence of non-nation state power centers represent the convergence of significant challenges and opportunities. The task is to address these opportunities both directly and indirectly. One course for confronting these challenges is confidence in the war fighters' abilities to test doctrine and TTPs through Operational Engineering, with result in fielding full mission capabilities around the hard kernel components faster then the opposition. This will allow the Combatant Commanders to feel they are receiving a truly value added system, i.e., qualified people and effective equipment, which is delivered supporting their execution of assigned missions. This will be the Operational Engineering legacy in producing the system-of-systems, a family of mission capability packages available off the production line directly to the front line.

These recommendations highlight the need to capitalize on the existing and evolving DII/NII infrastructure. The architectural and engineering backbone of family-of-systems interoperability requires acceptance and implementation of common standards, including compatible interpretations of those standards. The iterative engineering testing of this interoperability can be accomplished through the facilities such as the emerging JDEP. As introduced above, the metric of Program Manager delivery of promised mission capabilities, constitutes a measure of MISSION SUCCESS for the several levels of Commanders. Finally, test these capabilities in stressing field conditions that exceed those expected during the most stressing combat levels in order to provide an acceptable margin of risk. These offer the opportunity to remove some of the normal uncertainty and confusion when the fog of change or conflict comes over the horizon. The key is to change the traditional Rules of the Road response to the fog, to not slow down, but to maintain speed or even accelerate in order to operate within any significant potential enemy's OODA cycle. This drives U.S. and allied forces to seize and retain tactical initiative and momentum while maintaining force synchronization in all geographic and environmental conditions; thereby magnifying operational shock upon enemy forces through speed and surprise. Operational Engineering is the vehicle, the evolutionary heir, embracing and expanding upon the traditional hard kernel of system engineering. Operational Engineering will enable the current generation of war fighters to successfully wage a modern adaptive 'blitzkrieg' and achieve JV 2010's, and its successor's, vision of Full Spectrum Dominance during this period of Revolution in Military Affairs and uncertainty.

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Authors' biographies

Russell Bryant is the Leader for Future Decoy Development in the Surface Electronic Warfare Systems Program Office, Program Executive Office for Theater Surface Combatants. Previously served as CVN Ship Life Cycle Manager in the Aircraft Carrier Program Office, Naval Sea Systems Command. Retired Reserve Lieutenant Commander with Surface Warfare, Nuclear Power, and Naval Control of Shipping/Convoy qualifications. Commissioned 1976 from the Rensselaer Polytechnic Institute NROTC program with a Bachelors of Engineering in Nuclear Engineering, and minor in History and Political Science. Active duty service: USS *Mississippi* (CGN 40); USS *South Carolina* (CGN 37); USS *Texas* (CGN 39); Commander Naval Surface Force, Atlantic Fleet (Readiness and Training) staff; and, Commander Naval Air Force, Pacific Fleet (Ship's Material) staff. Graduated 1997 from the Naval War College, College of Naval Command and Staff, through the Non-Resident Seminar Program. Graduated 1998 from the USDA Graduate School Leadership Development Academy, Executive Potential Program. Member of Defense Leadership and Management Program, Class of 2000.

John Flynn is the Battle Force Operations and Engineering Leader for PEO Theater Surface Combatant participation in service and joint war games, exercises, and experiments. Previously the first head of Modeling and Simulation (M&S) in the AEGIS Program Office where he pioneered the use of distributed M&S. Previously served at NSWC, White Oak, as Head of System Design and Technical Direction Agent groups for the MK 116 Mod 7 ASW Control System. Graduated from Villanova University. Commissioned via NROTC in 1974. Sea duty aboard USS *Forrestal* (CV 59) and USS *Coontz* (DDG 40). A Captain in the Naval Reserve, serving a third command tour. He has a BS in Computer Science from the University of Maryland, graduated with highest distinction from the Naval War College, and completed the Strategic Studies Program at Old Dominion University. Graduate of The Catholic University Columbus School of Law and member of the Maryland bar.