New sensors such as carrier-borne SAR/MTI radars….

new sources of forward deployed payload such as converted Trident SSBNs….

and new weapons such as the Advanced Land Attack Missile . . .

. . . when networked together, will transform how today's Navy fights.

Naval Platforms, Weapons, Sensors, and Networks in the New Security Environment

The new security environment has a near and a more distant term. A major challenge will be to meet the near term demands of that environment while simultaneously preparing to meet the less certain but potentially more threatening demands that may arise in the more distant future. Many have identified this challenge and most agree that it will demand innovation, and some believe, truly radical innovation. This paper agrees that innovation will be necessary and in this last of three sections, suggests an overall strategy for achieving it, as well as specific, existing programmatic examples of opportunities for innovation in each of the mission areas discussed above. The basic strategy recommended is for the Navy to build on the capabilities of its existing and already planned platforms by pursuing near term opportunities for new weapons, sensors, and networks to link them together.

Two factors argue for this approach. First, because it is more relevant in the new security environment, there is less need for the Navy to engage in the truly radical innovation that that will be required of the Air Force and Army if they are to remain relevant in that same environment.[35] And second, an aggressive drive by the Navy to develop new weapons, sensors, and networks for its existing platforms in the near term will leave it well prepared for a more radical transformation should one become necessary in the more distant term.

Unlike the Air Force and the Army, the Navy's major platforms do not present fixed targets to an opponent when they are projecting power against that opponent, nor do they require permission from other countries to operate from their sea base. Thus, the Navy is less effected by access constraints, whether political or military, than are the Air Force and the Army. Certainly the Navy will face access constraints of its own, but meeting these challenges in the near term will not require radical transformation.

On the other hand, meeting the near term access challenges that the Navy will face will require a much fuller embrace of net-centric warfare than is the case today. In making this embrace, the Navy will need to give its existing platforms weapons, sensors, and networks linking them together that they do not have now. In doing so, it will sustain a process that has already begun, and which could lead to a more radical transformation should one become necessary.

Naval Platforms in the New Security Environment

In focusing on ways for the Navy to build on the capabilities of its existing platforms I am not implicitly arguing against developing and deploying new platforms, nor against increases in force structure. Rather, I am arguing that the weapons, sensors and networks described below, or others like them, will be both necessary and affordable in any future scenario. On the other hand, there remains uncertainty as to whether all of the Navy's currently planned platform modernization programs will be affordable under future defense budgets. This uncertainty is exacerbated by the fact that current shipbuilding accounts are already funding too few ships to sustain a 300 ship Navy for the long haul.[36] A Navy of at least 300 ships is needed to maintain a robust forward presence along the Mediterranean-Indo-Pacific littoral, and in the new security environment, that presence is the only way of assuring first-day-of-the-war access for U.S. forces in the future conflicts they are likely to face.

In broad terms, four defense budget scenarios may result from the Bush administration's ongoing defense review. Which scenario occurs will depend upon whether the DOD topline is raised or held steady, and whether budget shares among the services are held roughly equal or are reallocated based on a new national military strategy. The arguments I have made in the first section argue for a scenario in which the Navy gets an increased share of the DOD budget, whether the overall DOD budget rises or holds steady. In both cases, the Navy would receive more funding, but both outcomes presume the adoption and forceful implementation of a new military strategy in which the prime measure of effectiveness for U.S. forces is the ability to gain and exploit access. Absent such a military strategy, and past history would certainly argue against expecting one, service budget shares are likely to remain roughly equal. In this case, a rise in the DOD topline would still lead to more naval funding, but less than in the first two cases, and of course no rise in the DOD topline would leave the Navy where it is today.

In all these scenarios, the Navy will likely face roughly the same set of external demands, because the forward presence and first-day-of-the-war combat power it already provides so closely match the demands of the new security environment. At one extreme, this means that the Navy faces the potential challenge of significantly improving its ability to gain and exploit access at roughly today's budget levels, with the ships and aircraft it already has or which are already in production. In this scenario, the Navy will have no choice but to focus with some urgency on improving the weapons, sensors, and payloads of its existing platforms due to funding constraints. I will show below that there are substantial opportunities for such improvements. Furthermore, these improvements will be necessary in any funding environment, because the capabilities they provide will be needed regardless of which major platforms the Navy buys, and regardless of the eventual size of the fleet that results.

At the same time, it is important to note here what the costs will be if the Navy is forced by funding constraints to forgo modernization and replacement of some its existing platforms. I assume that because the Navy's forward presence translates directly into first-day-of-the-war access, because the degree of forward presence is directly dependent on force structure, and because today's 300 ship Navy already falls short of providing the level of presence desired by regional CINCs and national agencies, it is unlikely, even if it so desired, that the Navy would be allowed to fund future platform modernization accounts with reductions in force structure. More likely, if the Navy's budget stays constant, is the opposite scenario, in which some degree of future modernization is forgone in order to maintain today's force structure.

The two naval platform modernization programs most commonly described as politically vulnerable are Joint Strike Fighter (JSF) and DD-21.[37] Both share the political burden of having to compete in some eyes with modern platforms that are just entering production, the F-18E/F and Flight 2A DDG-51. But JSF and DD-21 will also provide significant new capabilities if successfully developed and deployed.

The Case for JSF

The Navy variant of JSF will arguably be the most capable strike fighter in the world if it is developed and deployed. It will have all aspect stealth, a 900 mile unrefueled radius of action, and double the internal payload of the other JSF variants as well as F-22.

All aspect stealth will reduce JSF's radar cross section both against other fighters and against ground-based radars. Compared to non-stealthy aircraft, JSF will therefore reduce and in some cases eliminate the need for dedicated defense suppression/destruction escorts. Its 900 mile radius of operation will give at least a portion of the carrier's air wing an ability to conduct unrefueled strike operations at more than triple the range of today's F-18C. And with the ability to carry both air-to-air armament and a pair of 2000 lb. bombs internally, the Navy JSF will essentially combine the air-to-ground capability of the F-117 and the air-to-air capability of the F-22, making it the only stealth fighter that will truly replicate the multimission payload capabilities of today's non-stealthy strike fighters.

These capabilities will have particular utility in an access-constrained security environment because in combination they will greatly improve both the freedom of maneuver and the first-day-of-the-war deep strike capability of the carrier force.

The Case for DD-21

DD-21 will enable four potentially revolutionary steps if it is developed and deployed. Its two 100 mile range 155mm guns are being developed explicitly to support the Marine Corps' Ship-to-Objective-Maneuver (STOM) concept. Deployed on DD-21s beyond line-of-sight from an enemy's coastline, these guns will clear the landing areas for long range V-22s and provide fire support to the troops those aircraft deliver from over-the-horizon amphibious ships. At the same time, TBMs launched from its 120 VLS cells will provide counter-battery fire against opposing artillery systems within a 200 mile radius, thereby helping to protect V-22 landing zones from indirect fires.

DD-21 will have a much smaller radar and IR cross section than DDG-51, which itself has a lower cross section in both spectra than traditional destroyers and frigates. This dramatic reduction in cross section will both reduce the acquisition range of an antiship missile's terminal seeker and greatly increase the effectiveness of the ship's countermeasures against that seeker.

DD-21 will also be a more automated ship, with a design goal of a crew of less than 100 compared to the 350 person crew of a DDG-51. This will significantly reduce operating costs, and therefore lifecycle costs, which along with a unit cost goal of $750 million, will produce a revolution in surface ship cost-effectiveness.

Last, DD-21 will introduce, or more accurately, reintroduce electric drive into the fleet. In the near term, electric drive will also contribute to the revolution in cost-effectiveness by allowing for the more efficient operation of the ship's propulsion plant, reducing fuel consumption which is another major operating cost driver for today's surface combatants. More important in the longer run, electric drive will also enable the development of an all electric ship.

An all electric ship could freely and rapidly shift all of the power it generates between propulsion and other uses, and in the future those other uses will likely include solid state lasers and electro-magnetic guns. The marriage between an all electric ship and powerful solid state lasers could produce a highly effective cruise and ballistic missile defense system with an infinite magazine, as well as an organic, anti-satellite surveillance asset. The marriage between an all electric ship and electromagnetic guns would significantly expand magazine capacities by eliminating the need to store shell casings. And last, by eliminating large hydraulic and mechanical systems, an all electric ship built out of modules connected only by power and data cables would introduce the concept of "life cycle modularity" in which new ship modules could much more easily be added or replaced over the course of a ship's lifetime.

Sensors, Weapons, and Networks for Gaining and Exploiting Access

The need to gain and exploit access in the new security environment will drive the Navy toward better sensors and weapons, and toward networks that link them together and process their output more effectively. There are both immediate opportunities in this regard, and opportunities which demand further development. The rest of this section will look at each of the warfare areas described in the second section, and describe some of these opportunities, and show how they address the access challenges the Navy needs to meet.

Undersea Warfare

The ASW and Mine Countermeasure problem in the littorals will always be difficult. But tremendous progress has been made in the ten years since the end of the Cold War on the main challenges in these areas. Compared to other warfare areas, ASW and MCM pose particular challenges in the areas of sensors and, to a slightly lesser extent, weapons. Networks are very important in ASW, but the networking technology needed is less demanding in many ways than the networking requirements in AAW. Networks are less important to MCM.

ASW Surveillance Sensors. The primary ASW challenge has always been wide area surveillance, and the main challenge initially posed by the new security environment in this mission area was a wide area search problem. Sound propagates better in deep water than in shallow water, and non-nuclear submarines can remain silent for extended periods when allowed to patrol small areas near their home ports at low speed. Using passive acoustics to search for such submarines is much more difficult than it was to search for relatively loud Soviet submarines operating in deep water during the Cold War. On the other hand, active sonars encounter serious problems with clutter in shallow water, much as early radars did when forced to look down at targets flying over land. And even in shallow water, the water column still remains relatively opaque to non-acoustic energy, limiting the role of RF and laser radars as long-range sensors.

Two new systems stand out as first steps toward gaining a wide area search capability in the littorals. The first is called the Advanced Deployable System (ADS) and the second is called Distant Thunder. ADS is a passive ocean bottom array that can de deployed by a surface ship, and whose output is currently collected and processed ashore via fiber-optic cable. Distant Thunder is primarily a signal processing adjunct to existing ASW combat systems, combined with legacy, air-droppable, active sound sources and a relatively simple data link that uses existing UHF radios on participating platforms.

Unlike the Cold War Sound Surveillance System (SOSUS) arrays, which listened for low frequency, narrow band tonals propagating outward horizontally along the deep sound channel, nodes in an ADS array look upward along what is called the Reliable Acoustic Path (RAP). ADS is a derivative of the Cold War Fixed Distributed System (FDS) program, which was an attempt to repair the ASW barrier strategy by using many simple passive sensors in an upward looking array that used the reliable acoustic path (essentially the direct path) rather than the deep sound channel. Each sensor would cover a small cone of the ocean column, and fiber optic cable provided the bandwidth to network a vast array of these small sensors and bring their output ashore for processing.

Distant Thunder adds commercial off the shelf (COTS) processing to existing towed arrays on ships (and potentially, submarines) and air-deployed sonobuoys, and links the processors together using legacy radios with modems to form a network that can do bistatic or multistatic processing of the echoes from the air-dropped sound source. The essence of Distant Thunder is that it uses both spatial and temporal processing to extract a submarine's echo from the clutter and reverberation. Long wavelength towed arrays allow spatial processing that can eliminate clutter and reverberation entering the array's sidelobes, and temporal processing allows reverberating echoes from the same object to be compared over time, thereby exploiting the fact that a submarine's echo loses less of its higher frequency spectrum in that time than do objects sitting on the bottom or floating on the surface.

One of the original concerns about Distant Thunder was that variations in bottom topography and content would interfere with its temporal processing capability, but worldwide experiments have demonstrated excellent performance over a wide range of environments. Like all acoustic sensors, performance will vary in practice depending on many circumstances, but Distant Thunder promises to return a substantial portion of the detection ranges initially lost when the Navy first shifted its focus to shallow water ASW. Another benefit of Distant Thunder is that it demonstrates long range performance under a wide variety of acoustic conditions, including the very common case in the littoral where sound is refracted away from the surface, a condition which drastically reduces the performance of a traditional, hull-mounted sonar.

Distant Thunder is also a great example of the incredible power of networked sensors, and the relative ease of backfitting such a capability onto legacy platforms once the substantial initial challenge of developing the necessary signal processing algorithms is completed. Distant Thunder can be backfitted onto any towed array ship or submarine, and onto LAMPs helos and P-3s. For example, on surface ships with the SQQ-89 ASW system, the physical footprint of a Distant Thunder backfit consists of one server and two laptops.

Specialized periscope or mast detection radars can also play an important role in the ASW search problem. Even during the Cold War, Soviet nuclear submarines regularly exposed a periscope when seeking a torpedo fire control solution against the fast ships of a Battle Group. And of course radar has an important role to play in preventing diesel submarines from snorkeling to recharge their batteries. Thus, a combination of speed, and radar deployed to search within the limiting lines of approach created by that speed, have always been an important ASW tactic against all submarines. Likewise, radar flooding in which a large area is flooded with RF energy so as to set off a submarine's radar warning alarm whenever it exposes a mast is also a traditional tactic against diesel submarines. But specialized mast detection radars like the APS-137 experience tremendous false alarm rates caused by both sea state and other floating objects and debris when their detection threshold is set low to maximize range.

The Automatic Radar Periscope Detection and Discrimination (ARPDD) program is developing the capability to process APS-137 returns in such a way as to allow very low detection thresholds (i.e. long range) and very low false alarm rates. Very impressive results have already been demonstrated in shipboard experiments, but unlike Distant Thunder, ARPDD needs further development time to simplify the massive processing capability it now requires before it can be backfitted onto legacy P-3 and LAMPs platforms.

ASW Weapons. Torpedoes remain the primary ASW weapon in the littoral environment, although this environment also presents them with great challenges, particularly lightweight torpedoes, which are fire and forget weapons. Like all fire and forget weapons, the relatively small aperture and limited signal processing available to a lightweight torpedo's active seeker makes for problems in shallow water where there is a lot of clutter and the target is relatively small and moving slowly. The Mk. 50 modification to the Mk. 46 lightweight torpedo provides an initial response to this problem, and the more ambitious Mk. 54 a more robust response in a few years.

There is also an alternative ASW weapon opportunity that grows out of the intersection between MCM and ASW. One of the challenges in the organic MCM program is to do in stride mine neutralization and clearance from a helicopter, and the Rapid Airborne Mine Clearance System (RAMICS) program's approach to this problem may provide another ASW weapon opportunity as well. RAMICS is discussed in more detail below.

A Common ASW Operational Picture. One of the legacies of the formidable passive acoustic detection ranges possible in ASW during the Cold War is the tradition of relatively autonomous operation amongst the Navy's main ASW platforms. When the Soviet Navy finally deployed very quiet nuclear submarines near the end of the Cold War, the need for more coordination arose. Today, coordination is even more important, especially to give the ASW commander and all of his forces a wide area picture of the ASW battlefield. Such a picture would allow better utilization of multiple, often evanescent contacts against the same target produced by different sensors; it would give units knowledge of environmental conditions over a wide area, allowing them to better predict the performance of their sensors as they move about the battlefield; and it would identify resulting “holes” in ASW coverage where search assets could be concentrated efficiently.

Most of the individual pieces of work needed to accomplish this task are relatively simple, such as using common operational protocols when processing and communicating data, and using the same environmental models. But the task is complicated by the need to integrate these activities across many platforms.

MCM Sensors. As with ASW, sensor performance is central to success. And again, the beginning of the problem is always to detect and identify the mines in the first place. In the new security environment, this challenge is further complicated by the need to make such a mine hunting capability organic to the Navy’s forward deployed Battle Groups, Amphibious Groups, and Submarines.

The key opportunities in this area lie in the prospects for very compact, imaging sonars and lasers able to detect and identify mines in the water column and on the bottom. Because these sensors can be made very small, they can be towed by smaller helicopters such as the CH-60, put on a surface ship-launched and controlled, semi-submersible vehicle, or even inside a torpedo-sized unmanned underwater vehicle (UUV) launched and recovered from a submarine. Through the regular, peacetime employment of these sensors, the Navy can map the ocean bottom, particularly near key approaches or chokepoints. Doing so will facilitate the location of mines, or the “deltas” from the peacetime picture, that will allow the Navy to rapidly focus on areas to avoid, or if they are critical, areas to clear. The unique advantage of the submarine-UUV combination is that this sensing can occur regularly without raising suspicion.

Many of these sensors will be common to the dedicated and organic MCM force once fully developed, but in many cases, full development will not occur until the middle of this decade. In the interim, hull-mounted mine avoidance systems that are adjuncts of legacy high frequency sonars on forward deployed forces will be needed, as will a full commitment to the preservation of the dedicated MCM force and to the continued forward deployment of a portion of it.

MCM Weapons. Once identified, mines need to be neutralized or destroyed. In many cases, the instruments that accomplish this purpose are not really weapons, but so called influence devices designed to create the signature needed to set off the mine in a way that does not destroy the mine sweeping platform. An influence sweep usually requires a platform that will not itself set off the mine, but which can tow a vehicle that will, hence the long tradition of relatively small, dedicated minesweeping ships with low magnetic and acoustic signatures. More recently, helicopters have been employed to tow influence sleds, but the size of the latter has required the towing services of heavy lift helicopters like the massive CH-53. Some of the same trends which will allow smaller MCM sensors will also allow smaller influence sleds, enabling an eventual transition to a CH-60 platform, and in turn allowing forward deployment on existing carriers, surface combatants, and amphibious ships.

In addition to influence sweeps, MCM forces also must have the ability to individually approach and remove or destroy all the mines it has found, because influence sweeps trade off speed for a reduced certainty that a minefield has been truly cleared. Here, one encounters perhaps the slowest and most labor intensive naval warfare area, in which today's dedicated MCM force utilizes explosive ordnance disposal (EOD) divers, marine mammal systems (MMS), and remotely operated underwater vehicles

New approaches to this problem designed for use by organic MCM forces focus on helicopter-deployed systems. In the nearer term, a helicopter-delivered, remotely operated underwater vehicle will be deployed that can approach an already identified mine and explosively destroy both itself and the mine. In the longer term, the RAMICS system described above is being developed. RAMICS will combine a LIDAR and a Gatling gun firing supercavitating, 20mm projectiles. The LIDAR would be used to search for and identify mines, and the gun's projectiles would disable or neutralize it by penetrating the mine's shell and injecting a chemical initiator into it.

The MCM Network. Unlike sophisticated networks like Distant Thunder, and those that will be described below for AAW and strike warfare, the main network in MCM is human, and the center of this network is the dedicated MCM force. This is to say that even more than ASW, MCM success is not a science but an art that requires practice and extensive, detailed knowledge, and which is therefore extremely perishable. A dedicated MCM force is the home for this expertise, because it is the only place in the Navy where officers will do nothing but train for MCM, and where the intelligence on foreign mines will be sustained.

Also, the nature of the entire undersea warfare threat, and particularly the mine threat, is that its most challenging manifestations have primarily “purple” and “green” consequences. In other words, an aggressive, inshore mining campaign by an opponent will more directly impact the projection of Army and Marine Corps power than it will purely naval power, and even when the Navy does face a serious mine threat, it will usually arise when it is operating in direct support of the Marines, as in the NSFS mission. Combined with an aggressive MCM program, this might lead some to advocate the eventual dissolution of the dedicated MCM force for narrow budgetary purposes. A salutary warning of the likely consequences of such a decision is provided the consequences of the Air Force's decision after the Gulf War to retire its dedicated air defense suppression assets in the belief that stealth would make such a dedicated force unnecessary.

Antiair Warfare

Throughout the Cold War, the main AAW threat to U.S. Navy Battle Groups was the long range, air and submarined-launched, antiship missile. This threat presented itself at great distances from the Soviet homeland, and was supported by an ocean wide surveillance system. The seriousness of this threat provoked major attempts by the Navy to deal with it at every step in the engagement sequence. Efforts were mounted to defeat or fool the surveillance system, to attack the launch platforms before they could launch their weapons, to take multiple shots at the weapons themselves if they leaked through a battle group's outer defenses, and to defeat the weapon's seeker in the terminal phase with both active and passive countermeasures. All of these defensive measures required depth, and depth was naturally provided in this Cold War mission area by the great range at which Soviet sea denial operations against U.S. Battle Groups were mounted.

The main problem with the littoral AAW threat is that this depth is largely absent, both because the U.S. Navy seeks to close with its adversaries, and because those adversaries are generally constrained anyway to operations within the littoral battlespace. This means that an adversary's launch platforms will be buried in the clutter and noise of the littoral environment, either on land or in shallow inshore waters where it is easy for them to hide. It also means that the surveillance system that cues those launchers need not approach ocean-wide coverage, but rather must only aspire to cover a radius of several hundred miles outward from the coast. And finally, because ASCM weapon engagements will usually occur over an even shorter range within the contested littoral battlespace, the specific weapons used can be relatively short range, sea skimming missiles rather than the high arcing AS-6s and SS-N-19s of Cold War fame.

All of these factors conspire to radically compress an AAW engagement in space and time, reducing the role of the outer air battle, and reducing the number of shots available during the inner air battle. For the most serious sea skimming ASCM threats, launched from platforms that have successfully approached a Battle Group in the littoral clutter, the AAW engagement will begin when the attacking missile approaches the targeted ship's radar horizon – say 20 miles – and will be over, for better or worse, within one or two minutes.

Three interrelated steps need to be taken to counter this threat. First, elevated sensors need to be developed which can eliminate or greatly reduce the clutter in the littoral environment which allows ASCM launchers to hide, and which also prevents missile detection until the terminal phase of an engagement. Second, weapons need to be developed that can function in the same cluttered environment against small, fast targets. And third, these sensors and weapons need to be linked together in such a way as to allow an elevated sensor to provide the information needed for another platform to launch a defensive weapon against the incoming weapon from over the radar horizon.

If ASCMs are an old threat presenting itself in a new way, TBMs are a new threat that presents itself in a way that early pioneers of the Cold War outer air battle will recognize. TBMD engagements may occur in a relatively compressed time frame, but they also occur over great distances, and once again, the challenge is to fill that extended battlespace with multiple engagement opportunities, each of which will require the same tight integration between sensors, weapons, and data networks as will ASCM defense. The difference in the geometry of the intercepts will mean however that sensors for TBMD will generally be upward looking from the surface instead of downward looking from the air. They will therefore not face clutter problems, but they will need to precisely track small targets at long ranges, moving at great speed, and incoming from very high altitudes.

In principle, ballistic missiles can be attacked at any point in their trajectory, and for long range ballistic missiles, each of the main segments of its trajectory offers an opportunity for a specific form of attack possessing a unique set of advantages and disadvantages.

The boost phase offers a brief opportunity for a shot at the missile when it is most vulnerable, when it is easiest to discriminate from its background, and when the debris from a successful attack will fall well short of its objective. However, boost phase intercepts must be completed before the booster burns out, which creates very demanding engagement timelines, and under many combinations of booster burn time and geography, makes it impossible to implement using surface or air-launched interceptors that must stand well off from an opponent’s launch sites if the latter are well inland. This is the reason that Cold War advocates of missile defenses were driven into space in an attempt to gain the benefits of boost phase defense against Soviet ICBMs, while today, ironically, opponents of today’s National Missile Defense program propose ground or sea-based boost phase defenses because, for geographic reasons, they would be ineffective against Soviet and Chinese ICBMs, but quite effective against a notional North Korean ICBM. Under most circumstances, ground or sea-based boost phase defenses will not be effective against very short range TBMs, such as the SCUD, because their booster burn times are so short that there are essentially no geometries in which a boost phase intercept would be feasible.

The mid-course phase of a missile’s trajectory is most relevant for longer range missiles which leave the atmosphere during this phase. This is by far the longest phase, extending from booster burnout to atmospheric reentry, which means that it gives the opportunity for multiple shots, and because it is a gravity and drag free environment, very small kill vehicles with very precise IR seekers can be used to attack targets at this stage. On the other hand, the same environment also makes it very difficult to distinguish between a missile’s warhead and any debris surrounding it, whether that debris is generated accidentally or intentionally as a countermeasure, because there is no atmosphere to filter out the heavy from the light objects. TBMs of all but the longest range do not ever completely leave the atmosphere, which does not mean that they do not have a mid-course phase, but it does mean that the IR seekers that long range interceptors use in this environment must be cooled to prevent atmospheric heating from blinding them.

The terminal phase of an engagement, defined either as that period after a long range missile has begun entering the atmosphere, or after a shorter range missile begins diving on its target, is again very short, offering fewer shots, but allowing for discrimination between warheads and debris based on the differential rate that the atmosphere decelerates their fall. More important from the TBMD perspective, the terminal phase is the only phase that allows a collocated surface-based radar and interceptor to begin and complete an intercept.

This discussion will focus on the near term opportunities for responding to the near term TBM threat, which if it carries a WMD payload, will likely be chemical rather than nuclear, but is most likely to carry a conventional payload and possess more accurate guidance, making them a much greater threat to ports and air bases ashore than were the Iraqi SCUDs.

Linebacker Projects TBMD Ashore. Air bases, ports, and other soft, fixed, high value targets will all be threatened by opposing TBMs, and the land-based forces which must use these bases face a double bind in trying to protect them. TBM defenses will be necessary to limit the threat to these bases, but land-based TBMD systems are themselves among the most difficult units to deploy, consuming large quantities of scarce, outsize airlift, which in turn limits the rapid deployment of the forces those TBMD systems are designed to protect early in a conflict when they are needed most.

Out of this conundrum, the Navy developed Linebacker, a TBMD system that is an evolution on the existing Aegis-Standard Missile capability. Linebacker involves minor modifications to the Aegis radar system itself, a more substantial modification to the SM-2 Block IV missile’s fuzing and warhead section, and Link-16 compatible data links and processing upgrades that allow both receipt and transmission of missile tracking cues, either from other radars or from national systems.

The fewest number of modifications were necessary to the Aegis SPY-1 radar because it has already demonstrated repeatedly in real world situations that it can track TBM targets, including repeated tracking events during Desert Storm and in the waters off of Taiwan in March, 1996. The Block IVA modification to the SM-2 adds a forward looking fuze to the warhead which utilizes angular rate information from a new IR sensor, and range and range-rate information from a new very high frequency RF transceiver, or radar. In addition, the Block IVA will retain the original Block IV’s capabilities against aircraft and cruise missiles, which means that Linebacker will not require a dedicated SM-2 variant. And finally, the Link-16 compatible networking used for Linebacker is primarily used to exchange track cues that allow better radar energy management.

For example, a Linebacker ship might receive a track cue from a national sensor that told it to look up at a certain quadrant of the sky. By focusing its RF energy on that spot, it will see the TBM target much sooner than if forced to search the entire sky for it itself. By seeing the target sooner, the Linebacker ship may also get several shots at it rather than only one. In the same way, an Aegis ship may also share track cues obtained by its own SPY-1 with a Patriot PAC-3 battery ashore.

Beyond Linebacker: Theater-Wide and Directed Energy. Linebacker, and the Area Wide System that it will evolve into as it is widely deployed on Navy CGs and DDGs, will provide relatively limited geographic coverage, requiring that Linebacker ships remain very close to the targets they are defending ashore. This is a constraint common to all terminal phase defenses. One challenge therefore is to further extend the TBMD battlespace out into the mid-course phase. This is the objective of the Navy’s theater-wide program, which will use a specialized SM-2 variant with a kill vehicle like that used in the NMD program. Theater-Wide embraces considerably more risk than does Area-Wide, in return for a considerable potential gain in capability.

The risk inherent to Theater-Wide will be resolved over the course of the coming decade, which is also the period during which WMD-armed ballistic missile threats are expected by some to emerge. The main role of Theater-Wide will be in dealing with this threat, because a credible response to this threat will require the full utilization of the TBM engagement sequence in order to get as many shots as possible. Credibility in this mission is crucial because Theater-Wide’s role will not be limited to actually defending against these threats in the relatively unlikely case that they are actually used. It will also play the all-important role of extending defense to important potential allies in peacetime, which do not possess their own deterrent forces, and which need therefore to be provided reassurance that a decision to provide the United States access will result in a concomitant decrease in their exposure to nuclear blackmail.

At the other TBMD extreme from Theater-Wide is the eventual development and wide deployment of conventional TBMs with precision, GPS guidance and wide area, sub-munition payloads. Systems like Area-Wide and Patriot PAC-3 will not be well-suited to countering this type of threat if and when it becomes truly ubiquitous, which has already led to an interest in directed energy, or laser weapons for highly capable terminal defenses. In the effort to develop such lasers, the Navy will lead in the effort to produce solid state or free electron lasers which are powered by electricity, rather than the chemically-fuelled lasers under development in the Air Force and the Army.

TBMD and the Navy’s Surface Combatants. The importance of ship-based TBMD in the new security environment has consequences both for the Navy’s current shipbuilding and modernization programs, as well as its future research and development. In the first category, the wide deployment of first the Area-Wide and then the Theater-Wide system will require vigorous execution of the Navy’s Cruiser modernization program, a four stage set of upgrades to its fleet of 27 Aegis cruisers that will unfold over the coming decade.

In the more distant term, the likely future conventional TBM threat argues for an aggressive pursuit of the all electric ship toward which DD-21 is a first step. The synergy between electric drive and solid state lasers is a powerful one in that electric drive allows the majority of a ship’s power to be diverted from propulsion to another purpose, and solid state lasers can use that electricity to create a terminal phase TBMD system with an essentially unlimited magazine.

Important elements of the Navy’s TBMD and ASCM defense programs are common. The Block IVA SM-2 and the SPY-1 are common to both efforts, as is the Cooperative Engagement Capability (CEC) which I discuss separately below. On the other hand, the main sensor in the ASCM defense effort must be elevated and able to look down in the littoral clutter. Also, the networking requirements for ASCM are more demanding than those required for Linebacker. And finally, the ASCM problem demands better terminal ASCM defenses, which are irrelevant to the TBMD problem.

E-2 Radar Modernization Will Reduce Littoral Clutter. Central to the ASCM defense problem is a much better wide area picture of the littoral air space, particularly at the low altitudes relevant to the ASCM problem. The E-2 is the Navy’s primary AAW surveillance system but it is not currently well equipped for this task. As a relatively low frequency UHF radar, the existing E-2 APS-145 radar has tremendous difficulty detecting targets in the littoral for two basic reasons.

First, more than higher frequency radars like that on the Air Force’s E-3, the E-2 has trouble picking out so-called low doppler targets on the littoral. A low doppler target is one whose closure rate relative to the surveillance radar is low. Historically, the prime radar signal processing routine for look down radars has been designed to exploit high doppler targets, i.e. ones closing on a path normal to the surveillance radar at a very high rate. An ability to track low doppler targets in the littorals is critical because ASCMs, as well as aircraft, all present themselves as low doppler targets no matter how fast they are going unless they are flying normal to the overhead surveillance radar.

Second, mechanically scanned UHF radars have inherently larger sidelobes than do higher frequency radars, which makes them more susceptible to both intentional jamming, and to inadvertent electromagnetic interference (EMI). EMI is particularly troublesome at the lower, roughly 400 MHz frequencies where the APS-145 operates because there are so many powerful commercial occupants near this band.

The E-2 radar modernization program (RMP) will defeat these problems using two techniques that will sound broadly familiar from the earlier discussion of Distant Thunder. First, the APS-145 will be replaced by a digital, phased array radar called the ADS-18, whose 18 element array will allow electronic scanning over 160 degrees, and which will mechanically rotate to provide 360 degree coverage. The phased array antenna allows the radar to reduce its sidelobes electronically, significantly reducing the jamming and EMI problem. It also provides more gain in the main lobe, giving better detection ranges. Second, the ADS-18 will also allow temporal processing by providing three complete sets of measurements of the RF energy returning from a single spot, which will allow it to distinguish the moving target within the fixed clutter background of that spot because the target will move slightly during the interval between each of the three pulses.

ADS-18 will provide a quantum leap in the ability of the E-2 to detect ASCMs in the littoral environment, as well as a raft of other important targets. The next step is for the E-2 to provide its track information to surface ships in a way that maximizes their ability to shoot down the missile. This can be done in three ways, roughly corresponding to degrees of both capability and risk, and the Cooperative Engagement Capability (CEC) is central to all three.

The Centrality of CEC. CEC is a very sophisticated data link that allows different platforms to share tracking information on targets with a speed and accuracy that allows one platform to shoot a weapon at a target that another is tracking. In practice, CEC enables both very accurate cueing, to provide warning to another platform that it is under attack by a target it cannot yet see, and to maximize that platform’s radar energy management so that it can begin defending itself as soon as possible. More ambitiously, it allows for actual over the horizon engagements, where one platform launches a weapon that another guides to the target. In all cases, CEC extends the battlespace available to combat the ASCM threat, and this is particularly the case when CEC is combined with E-2 RMP, as it will be if the latter program is funded.

At a minimum, CEC can give warning to any ship with terminal ASCM defenses that it is going to come under attack from a very specific azimuth, allowing it to aim its ship self defense systems at that point on the horizon and to prepare to deploy decoys.

For ships with Standard missile or Sea Sparrow capability, CEC will provide cueing that allows search radars to focus their energy on the horizon, and will in some cases enable missile launch before the ASCM has broken the target ship’s radar horizon.

Most ambitiously, and here an X-Band illuminator must be added to E-2 RMP, CEC could enable SM-2 intercepts flown at the very limit of their kinematic range by using the E-2 for both target track and illumination. Such a capability was demonstrated in the Mountain Top experiment in January, 1996.

Evolved Sea Sparrow and SeaRam. Even with E-2 RMP, Aegis, CEC, and Block IVA SM-2, some ASCMs will leak through, and each of the Navy’s major combatants needs a robust set of terminal defenses, both active and passive, to deal with this challenge. The Evolved Sea Sparrow Missile (ESSM) and the Rolling Airframe Missile (RAM) are two approaches to creating an “outer” terminal defense, while CIWS is the inner ring. ESSM is a semi-active radar guided missile that can fit four at a time into existing VLS cells, while RAM is a shorter ranged system based on the Sidewinder AAM airframe, and has both an IR and a passive RF guidance mode. For the most modern ASCM threats, CIWS lacks range, and SeaRam is a program to replace CIWS with RAM using the same ship footprint.

For the most demanding missions, there may be a case for including both ESSM and SeaRam where possible. These systems will need to be combined with passive defenses which attempt to present false radar targets to the incoming missile which distract it from the real target. Here, radar stealth can play an important role for surface combatants, as DDG-51 has already demonstrated, and as DD-21 is designed to demonstrate further.

F-18E/F and Overland Cruise Missile Defense. Just as cruise missiles pose serious threat to ships in the littoral, they also pose threats to targets ashore. Overland cruise missile defense presents all the problems described above, with the additional challenge that the endgame of the engagement is more challenging because small aperture AAMs have more difficulty picking out cruise missiles from ground clutter than they do at sea. One element in the solution to this more challenging problem will be to use electronically scanned radars on strike fighters which can better guide AAMs into the narrow basket in which their terminal seekers can function against small cruise missiles. This is just one reason for the Navy to stick to its plan to fund an AESA radar for the F-18E/F starting in FY 05.

Strike Warfare

Four new factors dominate the strike warfare mission area. First is the revolution in precision weapon effects, the opportunity for which first became manifest in the Gulf War. Bombs which once needed to be dropped en masse by entire formations of aircraft to produce even a reasonable probability of hitting a single target can now be dropped in pairs or even individually by a lone aircraft against several targets with a high probability of success. And this capability will only grow in importance in cases where the threat of weapons of mass destruction demands the destruction of these weapons (and their supporting infrastructure) through precision strikes in the early hours of a conflict.

Second, because precision weapons have suddenly made successful attacks against fixed targets seem automatic, they have also highlighted shortfalls in the U.S.’s ability to attack mobile targets. The need to get better at attacking mobile targets will depend both on better sensor networks for detecting, identifying, and tracking them, but also on the more rapid delivery of weapons cued or targeted by those sensor networks.

Third, in a theme which has infused this paper, sensors, weapons, and weapon delivery platforms will all need to be linked together by data networks. These data networks will perform two crucial functions. They will enable the signal processing within sensor networks that will allow those networks to provide targeting rather than just cueing information to weapon platforms, and they will communicate that information to those platforms in real time, and in a format that enables the immediate launch of a precision weapon in response.

Fourth, traditional approaches to suppressing mobile radar-guided SAMs are facing diminishing returns in effectiveness. This is important because modern SAMs form the heart of the integrated air defense systems of the U.S.’s potential opponents, and those defense systems create access problems to the extent that they limit strike warfare capabilities.

Underlying these general factors effecting strike warfare are factors unique to the U.S. Navy in the new security environment. There is relatively more demand for strike from the sea capabilities because they face relatively fewer access constraints than do land based forces. In meeting this demand, the Navy needs not only to focus on better sensors, weapons, and networks, but also on maximizing the forward deployed payload that ultimately constitutes the upper bound on its strike warfare capability early in a conflict when that capability is most valuable.

A specific driver for more forward deployed payload at sea will be the need to preserve the option of large, surprise attacks against the delivery vehicles and command and control infrastructure of WMD-armed opponents, and against the ground-based infrastructure of those opponents with an over-the-horizon ocean surveillance system. The Navy has already taken one of the steps necessary to meet the demands for more strike from the sea capability, which was to make every combat aircraft in its carrier wings a precision strike fighter. With F-18E/F it will take another step down this road, both by producing a more capable precision strike fighter, and by further increasing the utilization of the carrier deck by reducing the number of separate aircraft types that must be operated and maintained on it.

On a parallel path, and again as a result of the precision revolution, both the surface and submarine communities have quickly grown to become partners with aviation in strike warfare. Here, the precision revolution enables the participation of these platforms because it allows them to stand well off from the battlefield and still produce precision effects on it. And this positive trend is being reinforced with the development of weapons like Tactical Tomahawk, which will provide an increase in capability over today's Tomahawk at half the price, and in the introduction of ship and submarine-launched TBMs like LASM and later, Advanced Land Attack Missile (ALAM).

The marriage of standoff precision weapons with the surface and submarine communities has already produced an additional quantum leap in what the Navy brings to strike warfare from the sea. But the new security environment has additional demands. The first is for more forward deployed naval payload, the second is for a better capability against mobile targets, and the third is for a strategy to transition seamlessly from today's approach to defense suppression to one that results in defense destruction. In describing the opportunities to meet these demands, the following discussion will look first at the highest leverage path to more forward deployed payload, which will include a discussion of both platforms and weapons. Then it will look at the opportunities in sensor networks for targeting mobile targets, and show how increasing the number of sensors in the network improves the precision of the targeting data it produces. Third, it will look at the future defense suppression/destruction challenge in light both of what is necessary in the near term, and what sensor networks may make possible in the more distant term.

Platforms and Weapons For Increasing Forward Deployed Payload. The aircraft carrier is a forward deployed platform, and its air wing is in some senses its weapon, and this combination is a relatively mature system. Interesting and valuable work is being done to improve the sortie generation capacity of existing and planned carriers and air wings, but the resulting improvements will not be revolutionary. Because the carrier will remain the centerpiece of the Navy's strike warfare capability, these incremental improvements need to be pursued, but another major source of forward deployed payload that can be exploited lies in the surface and submarine forces. This is because of the revolutionary progress made in long range, standoff precision weapons that surface and submarine platforms can deploy in their vertical launchers. This is particularly true in the area of TBMs, which represent the shortest distance between a strike weapon launcher and its target because they have such short times of flight. Short time of flight weapons will in turn play a key role in time critical strike, both as an element of the solution to some parts of the mobile target problem, and as a means of attacking fixed targets like air bases and weapon depots, whose value can change quickly and dramatically with time, particularly when they may contain weapons of mass destruction. The best vehicle to exploit this opportunity is the ALAM program, which is currently focused on meeting longer term Marine Corps fire support requirements, but which will also be an important strike warfare tool.

Also, for both TBMs and cruise missiles, GPS/INS accuracies are improving by an order of magnitude every few years, and will soon be measured in feet rather than tens of yards. As accuracies improve, the size of the warhead needed for a given lethality against a fixed target goes down as the cube of the reduction in miss distance, which means in turn that as payload weights go down, missile throwweights go down, missile sizes go down, and finally missile costs go down.[38]

The same trends that will improve the lethality and reduce the costs of standoff weapons will also improve the payload capacity of their launchers. This is because smaller missiles with the same lethality as weapons like the Tomahawk or LASM virtually give both submarines and surface ships much larger magazines without changing the internal volume of their vertical missile tubes. This is what engineers call a virtuous rather than a vicious circle and it represents a perfect example of the difference between increasing rather than decreasing returns on investment.

A final step forward in the capability of these weapons that should be grasped is the ability to provide real time bomb impact or damage assessment (BIA or BDA). Tactical Tomahawk will already provide the beginning of such a capability, and ALAM should be given it as well. At a minimum, standoff weapons should be designed to “scream” their last position prior to impact over a simple RF channel. More ambitious are schemes to allocate a small portion of the missile’s payload to a visual sensor that would deploy prior to impact, view the results, and broadcast them back over a more capable RF circuit.

Real time BIA and BDA are important because they reduce the number of weapons that need to be allocated to an attack, and the time needed to complete those attacks. BIA and BDA reduce the number of weapons needed because “shoot-look-shoot” tactics can be used, which eliminates the need to allocate two weapons for every target simply to compensate for the expected unreliability of a small portion of those weapons. Instead, additional weapons can be allocated after an initial salvo of one weapon per target only to compensate for those weapons that actually failed in the first salvo. Real time BIA and BDA reduce the time needed to make this compensation, thereby reducing the time during which the targets missed in the first strike remain uncovered. It is this last improvement provided by real time BIA and BDA that is most important, because current approaches to this problem often take hours or days, and against high value, time urgent targets like WMD sites, planners cannot afford to wait.

Additional forward deployed VLS payload compounds the advantages provided by further standoff weapon development. For example, using the roughly 20 inch diameter/20 foot length weapon template established by today's VLS tube, one can measure the benefits produced by using improved accuracy to increase payload. Assuming a 20 meter CEP, and using existing propellants, a TBM with a 250 lb warhead and a 500 km range could be developed with the same diameter and two thirds the length of today's VLS cell. Modest improvement in the specific impulse of its propellant would further reduce its length to 10 feet, allowing double stacking in a VLS tube. This would double the number of LASM-type weapons that a surface combatant could deploy, meaning that in its currently planned version, DD-21 could carry 256 rather than 128 LASM equivalents.

More dramatic in the near term would be the effect of converting Trident SSBNs into conventional, guided missile submarines, or SSGNs. Four Tridents are now available for SSGN conversion, and more may become available if deeper cuts are ordered in strategic offensive forces. In the cheapest conversion, with half the launcher volume unused, a Trident SSGN could carry seven VLS-equivalent weapons like Tomahawk or ATACMS in each of its 24 tubes for a total of 168.[39] With double stacking, this total could eventually be increased to 346. And finally, a smaller TBM designed from the beginning to be double-stacked in a surface combatant's VLS tube could be quadruple-stacked in packs of seven in each of an SSGN's missile tubes for a total of 672.

These additions to forward deployed payload are not important just because they will enable time critical strikes against mobile targets found by new sensor networks, but also because they will greatly expand the size of the "first night of the war" salvo available to a Battle Group commander tasked with the job of taking out an opponent's WMD and ocean surveillance infrastructures.

Near Term Sensor Networks For Targeting Mobile Targets. There is a strong mutual interaction between the accuracy of the target location information that a sensor network produces, the quality of the target classification information that it provides, and the strike assets which use that information to attack the target. In broad terms, the less precise the location and classification information, the more capability that needs to be organic to the strike asset. For example, a sensor network might provide wide area surveillance which provides only cueing quality target location information and little or no classification. In this case, the strike asset will need to be able to reacquire the target with its own sensors, positively identify it, and deliver ordnance on it should it not prove a false target. In general, this describes the situation today in mobile target strike, where the best surveillance assets are the first generation airborne SAR/MTI radars symbolized most strongly by JSTARS. These surveillance platforms provide limited geographic coverage of the battlefield, modest classification capability of moving targets, and target location information that is sufficiently imprecise to prevent direct targeting with GPS-guided weapons.

Of course, this capability alone is a giant step forward from the past, when mobile target strike consisted of strike aircraft flying low in daylight and visually searching for mobile targets, a tactic that would produce very high loss rates in the face of today's short range air defenses. For the near term, the road ahead in mobile target strike is therefore to more fully populate the battlefield with airborne SAR/MTI surveillance, and to improve the ability of strike aircraft to use the cueing information thereby provided.

From a naval perspective, this means guaranteed Battle Group access to a SAR/MTI surveillance platform, F-18E/F AESA with a SAR/MTI mode for reacquiring cued targets, an advanced tactical FLIR for cases when the target is not yet fully classified, and something like the GPS Aided Targeting System (GATS) to allow an autonomous targeting capability for GPS-guided weapons like JDAM and JSOW. Link 16 is central to this future because it will allow cueing information to flow from the surveillance platform to the two seat F-18F FAC in real time and in a format that allows immediate display on the latter's head up displays. Link 16 will come back into play once the FAC has reacquired, classified, and geolocated the target or targets by allowing it to pass targeting information in real time to an inbound F-18 strike package in a format that allows immediate insertion of GPS coordinates for their weapons.

The biggest question mark in this roadmap today concerns guaranteed Battle Group access to a SAR/MTI surveillance platform. P-3 AIP will provide SAR radar surveillance and precision targeting, but not an MTI mode, and even P-3s are sometimes denied access to some parts of the Indo-Pacific littoral. Global Hawk will often be available if bought in sufficient numbers, but it's payload is weight and power limited, one result being a limited MTI capability compared, say, to JSTARS. A serious opportunity for the Navy to consider is a Precison Surveillance and Targeting (PS&T) SAR/MTI platform based on the E-2 airframe, or even on a ship-launched medium to long endurance UAV. A PS&T E-2 would combine the SAR/MTI functionality of JSTARS with an Inverse SAR (ISAR) mode that enables surface search and mast detection. The development of the radar itself is low risk, but the integration of PS&T and RMP in the same air frame is at the low end of high risk. A near term alternative to full integration would be to backfit PS&T onto low time, pre-Hawkeye 2000 air frames that have had APS-145 removed. This option would be modeled on the ES-3 force model, with a total of 14 air frames filling two six plane squadrons available for Battle Group deployment and one two plane replacement air group.

Longer Term Sensor Networks for Targeting Mobile Targets. At the other extreme from the near term sensor network described above is one where the sensor network detects, identifies, and continuously tracks mobile targets with GPS-targeting quality precision. Provided such a network, large standoff weapon carriers would launch cruise missiles that the network would update in flight with sufficient frequency to bring within the very narrow reacquisition basket of a very simple terminal seeker. These weapons would be so precise that their payloads could be kept very small, which would reduce their size and cost, and allow their use in very large numbers. And finally, the data links enabling all of this would be both extremely jam resistant and covert, and their terminals would be small and cheap enough to be deployed on all platforms and weapons.

As a future to strive for, this picture is a worthy goal, but in its details it poses many significant technical challenges. Perhaps the most relevant of these challenges in the near term is the goal of having sensor networks that provide targeting information of sufficient quality to target time urgent GPS weapons. This challenge is relevant in the near term for two reasons. First, because of its true all weather performance, GPS/INS is rapidly becoming the preferred mode of precision weapon guidance. And second, most mobile targets spend most of their time sitting still, which from a targeting perspective makes them fixed targets that occasionally move at unpredictable points and for unpredictable durations. Thus an intermediate step in addressing the mobile target problem will be to develop sensor networks that track these targets while they are moving but precisely geolocate them only when they stop, and to develop time critical strike capabilities that can respond to this targeting information quickly enough to put a weapon on the designated aimpoint before the target moves again.

The key to sensor network precision is to put multiple rather than single sensors within line-of-sight of the target to be located, and to network those sensors so that their collective output can be processed. In general, two sensors with the capability to give an accurate bearing to the target, and separated by a fairly long baseline, can be used as a long baseline interferometer if networked properly. But errors creep into this system at multiple points. For example, the bearing information has an uncertainty of plus or minus x degrees, and the two sensor platforms only know their positions within a radius of x feet. Such targeting information is still useful, but would demand prosecution by a GPS-guided weapon with an expensive terminal seeker or submunitions.

Three sensors with better angular resolution, and better location information will do better, and work is now being done by DARPA to look at such a network of airborne SAR/MTI radars. Part of the technical risk in such networks lies in assuring the seamless transition from the MTI to the SAR mode or vice versa such that individual target tracks are not lost. As progress is made in this area the cost of the weapons needed to respond to network targeting will fall, because they will be asked to make up for less and less targeting imprecision in the terminal endgame.

Defense Suppression in the Near and Mid Term. The defense suppression/destruction problem is a subset of the mobile target problem, and it is simultaneously an access problem. Efforts now mounted to suppress defenses automatically subtract strike capabilities, because the same platforms perform both missions. These efforts also put an upper bound on aircraft strike capabilities, because U.S. forces now have more precision strike capability than they have defense suppression capability to assure it access. Hence, the new concept of a low density/high demand (LD/HD) asset. Thus, the defense suppression/destruction problem is one where effective new approaches to the problem would provide high payoff in freed strike assets, and fortunately it is also a problem that is uniquely suited to a networked sensor-time urgent weapon approach in the mid rather than the far term.

That is because mobile radar-guided SAMs like the SAM-6 and the SAM-10 differ from other mobile targets in that they must not only stop and remain immobile while they are performing their mission, but they must also emit high power RF signals during at least a portion of the time they are immobile in order to be effective. This is significant because it is easier to construct a very precise, passive RF emitter location system than it is to construct a radar-based system for tracking non-emitting mobile targets. A passive network of three sensors can exploit time-difference-of-arrival (TDOA) signal processing, which eliminates the tradeoff between accuracy and the angular resolution of the individual sensors, allowing for much cheaper, non-directional sensors, like the relatively simple Radar Warning Receivers (RWRs) that all tactical aircraft already carry. A TDOA network does requires a data link with very precise timing information, but Link 16 already provides that, and a TDOA network is still sensitive to errors in the position of its nodes, and errors will exist in an airborne network, though again, steady overall improvement in GPS system accuracies will continue.

Such a network, whether using airborne platforms, or in the more distant future, using unattended ground sensors, will enable defense suppression/destruction operations that resemble the way the Army now conducts counter-battery fire. In the Army case, a radar determines the location of enemy artillery batteries by observing their fires, and targets counter-battery fire that can be in the air before the incoming shells land. Forward deployed, TBM-firing surface ships and submarines will be in position to attack SAM batteries as soon as they light up their radars if a TDOA network is in place. Either Link 16 or UHF SatCom can be used by the network to communicate targeting information, and both surface ships and submarines will be able to maintain continuous connectivity at these frequencies.

In the nearer term, elements of this preferred mode of operation will at any rate need to be inserted into today's defense suppression forces in order for that force to keep pace with today's threat. But in addition, there are elements of today's defense suppression force that may not be part of a future, more net-centric approach to this problem, but which are both so important and so relatively scarce in today's security environment that their capabilities must be improved. One such program is the EA-6B ICAP update, and the other, more developmental program, is the AARGM/Quick Bolt upgrade to the HARM antiradiation missile.

EA-6B ICAP and AARGM/Quick Bolt. The ICAP program is important for four main reasons. First, it will introduce all digital jamming pods that are both easier to maintain and easier to update with new threat information. Included will be the first pods covering the lower frequencies of interest: including VLF surveillance radars that can track stealthy aircraft, and which are very hard to permanently take out because their antennas are so easy to repair or replace. Second, it will add a "look while jamming" capability to its receivers, allowing EA-6s to serve both as an ESM platform and a jammer, and allowing real time jamming responses to pop up emitters. Third, ICAP will introduce a long baseline interferometric antenna that enables it to calculate the range to an emitter, allowing it for the first time to target HARMs in the most effective "range known" mode. Finally, ICAP will introduce Link 16 onto the EA-6B for the first time.

AARGM/Quick Bolt is actually two separate development programs aiming to upgrade existing HARM air frames. AARGM is a nearer term program that seeks to give HARM a better capability against SAM radars that shut down in the midst of an engagement. It does this by giving its antiradiation homing (ARH) seeker the ability to use GPS to take several, inflight DF cuts on the signal it is homing on. This will reduce the initial rather large target location error inherent to current HARM targeting systems, making it possible to put a simple millimeter wave radar on the front of the missile which will search for and home on any vehicles in its view if and when the ARH loses its signal.

Quick Bolt is a more ambitious program that seeks further improvements against radar shut downs, better BDA, and a replacement motor that will give longer range at higher speeds in a smaller package. With regard to the motor development program, it seeks to make HARM faster and longer-legged, to better fight the “F-pole” battle against SAM-10s, and at the same time to make it shorter, because if launched from a non-stealthy platform, it will likely still lose the F-pole battle, which means that the HARM launcher will need to be stealthy, and current HARMs are too long for F-22s and JSFs to carry internally.