

Submarines In The Air Sea Battle (U)

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Abstract

(U) The Defense Department's Air Sea battle initiative reflects the fact that technology and geopolitics are conspiring both to force and to enable a deeper coordination between undersea, surface, air, and space operations. This is true at both ends of the conflict spectrum, as well as at points in between. At the high end of the conflict spectrum, an example of the forcing function is the potential anti-access problem in the Pacific theater posed by modern surface-to-air missiles (SAMs), and an example of the enabling function is the potential marriage of submarines, fast weapons, and organic Unmanned Aerial Systems (UAS) for use in time critical strikes against such systems. This presentation will summarize the approaches currently projected by air forces for defeating modern, ground-based air defenses; discuss the significant operational challenges involved with these purely airborne approaches to the problem; and note the technological opportunities presented by a complementary Air Undersea approach.²

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1 MODERN AIR DEFENSES AND THE ACCESS DENIAL CHALLENGE

(U) Land mobile targets are the enemy's center of gravity in both today's war on terror and possible wars against future peer competitors. In the latter case, the main challenge will be to gain access to and project power within a littoral battlespace within range of advanced land attack and anti-ship missiles. All of these so-called anti-access systems are land mobile and have acquired the precision that the United States first demonstrated on a large scale in Operation Desert Storm.

(U) A land mobile, long range, precision strike capability can evade the U.S.'s crushing ability to destroy fixed targets while simultaneously holding at risk the U.S.'s ability to use land bases. Combined with an ocean surveillance system and a terminal guidance capability, land mobile missiles can also hold U.S. naval forces at risk. Together, these two capabilities defeat the U.S.'s current approach to projecting power.

(U) The last 20 years of near constant combat operations have shown unequivocally that defeating mobile targets requires a persistent network of surveillance sensors and strike assets. Unlike traditional fixed targets that can be targeted well in advance of a conflict, mobile targets can normally only be found and targeted when they generate a specific signature associated with their mission. These signatures (and the sensors needed to exploit them) range from simple movement (moving target indicator {MTI} radar), operating internal combustion engines or high powered electrical equipment (long wave infrared {IR}), rocket or jet exhausts (medium wave IR), or radio and radar emissions (passive radio-frequency {RF}).

(U) Persistence is the key concept. In the surveillance realm it means sensors providing an unblinking, wide area stare, while in the weapons realm it means weapons that combine range, speed and basing mode in such a way that they are always available in timely fashion. Surveillance sensors need to be persistent because the mobile target signatures they exploit only occur intermittently, and the weapons need to be prompt because striking mobile targets is usually only possible when they are stationary. Thus, for example, if a targeting solution will only last for 20 minutes, the weapon to exploit it should not be more than 20 minutes away.

(U) In the access-unconstrained environment that has characterized the war on terror this has led to an explosion of unmanned aerial system (UAS) use as a source of persistent surveillance. Air breathing surveillance platforms will likely remain the primary sensor platform for dealing with mobile targets.

(U) All sensor platforms have line-of-sight or power/aperture constraints that limit the performance of their sensors. Ground-based sensors are least limited by power/aperture but usually most limited by line-of-sight, over-the-horizon backscatter (OTH/B) radars and high frequency radio direction finding (HF/DF) being the main exceptions to this rule. For satellites in geosynchronous orbit this relationship is reversed; line-of-sight is essentially unlimited but power/aperture limitations mean that only passive sensors such as IR and signals intelligence

(SIGINT) work. Satellites in low earth orbit reduce power/aperture constraints, allowing optical, synthetic aperture radar (SAR), and MTI radar sensing, but at the great cost of achieving only intermittent line-of-sight to any one point on the surface. High Altitude, Long Endurance (HALE) unmanned air systems (UAS) combine persistent line-of-sight coverage of a wide area with the ability to deploy sensors with relatively high power/aperture, hence their increasing ubiquity as the mobile target challenge has grown.

(U) The problem is that modern air defense systems will eliminate the sanctuary that airborne sensor platforms currently enjoy. To be specific, the increased missile range associated with so-called “double digit” surface-to-air missile (SAM) systems will force airborne radar platforms like JSTARS, U-2, and Global Hawk to stand off beyond the range of their radars and will prevent airborne electronic intelligence (ELINT) platforms like RC-135, EP-3, and Global Hawk from geo-locating RF emissions with precision.³

(U) Absent these persistent surveillance capabilities, it is impossible to deal with mobile targets, so dealing with double digit SAMs is a, if not the, key anti-access challenge. The problem is that current approaches to destroying modern double digit SAMs all depend on land and sea-based tactical fighters whose access to the theater presumes a prior solution to the access denial challenge posed by mobile, precision land attack and anti-ship missiles. This in turn presumes persistent airborne surveillance, which in turn presumes a solution to the double digit SAM problem.

(U) This is the vicious circle which lies at the heart of the future access denial problem. Submarines have become uniquely capable of breaking this vicious circle because of the development of time and frequency-difference-of-arrival (T/FDOA) ELINT signal processing techniques that can now be implemented using networks of even the smallest tactical UAS. Combined with a submarines’ traditional ability to provide a stealthy and persistent source of weapons in even the most access-constrained littoral environment, an organic UAS will provide submarines a fully organic capability to detect, identify, precisely locate, and quickly strike modern SAM engagement radars.

2 THE DESTRUCTION OF ENEMY AIR DEFENSES (DEAD) FROM UNDER THE SEA

(U) The core of DEAD from under the sea is a submarine with the ability to deploy small UAS and fast, coordinate seeking weapons. The UAS use T/FDOA to precisely locate radars and the fast weapons strike those radars before they relocate.

³ The best unclassified source on double digit SAMs is *Jane’s Land-Based Air Defense, 2009-2010, 22nd Edition* (Jane’s Information Group, Alexandria, VA: 2009) pp. 214-215, which cites a range of over 200 miles. JSTARS’ MTI radar is cited as having a range “in excess of 124 miles” in “Air Force Almanac,” *Air Force Magazine*, Vol. 93, No. 5 (May 2010) p. 131.

2.1 PRECISION ELINT

(U) The unique benefit provided by T/FDOA is that it enables ELINT with sufficient precision to target modern strike weapons that use the global positioning system (GPS) for guidance. A single RF receiver, no matter its aperture, can never by itself produce a targeting solution for such weapons because it has no means of compensating for the inherent errors in angular resolution that characterize its bearing measurements when used to triangulate the location of an emitter.

(U) True T/FDOA networks do not need to use bearing measurements to locate an emitter. Instead, two widely separated receivers are used to precisely measure and compare the time of arrival and frequency of the same signal pulse from an emitter. Roughly speaking, each set of measurements produces a hyperbolic line on the ground along which the emitter must lie and the two lines only intersect at one point.

(U) T/FDOA is computationally intensive and legacy T/FDOA ELINT networks therefore still needed to use large aperture antennas and accurate bearing measurements to achieve a targeting solution in a dense signal environment and a tactically relevant timeframe. The Defense Advanced Research Projects Agency's (DARPA) Advanced Tactical Targeting Technology (AT3) program successfully demonstrated T/FDOA signal processing that exploited the vast computational power now available in even the smallest package. AT3 enables the formation of a true T/FDOA ELINT network using very small omni-directional receivers deployable even on very small UAS.

(U) This makes an enormous virtue out of what would have been a big vice for a submarine-deployed UAS. Smaller is better for the nodes in an AT3 network because AT3 accuracy, though always much better than traditional, single platform, angle-of-arrival techniques, still varies with the nodes' range from and their relative separation in azimuth to the emitter. Small size and slow speeds create stealth and allow small UAS to get close and maximize accuracy.

(U) An added benefit of AT3 is that it works equally well against an emitter that only emits briefly and intermittently. This is important because modern SAM engagement radars are designed to operate in this way to eliminate their vulnerability to anti-radiation homing missiles such as the high speed anti-radiation missile (HARM) that depend on a continuous signal to destroy those radars.

2.2 FAST WEAPONS

(U) A fast, coordinate seeking weapon is equally important for DEAD from under the sea. Once a modern SAM engagement radar has begun an intercept, it will have exposed itself and a clock starts ticking until the engagement is complete, the radar can break down, and relocate to another operating site. AT3 can quickly locate the radar as soon as it emits, but that will be of no

use if a weapon only arrives after the radar has relocated. Air breathing weapons cannot provide such promptness from any kind of standoff distance but tactical ballistic missiles (TBMs) can.

(U) Like AT3-equipped UAS, a GPS-guided TBM can be acquired off the shelf and deployed in existing submarine and surface combatant launchers for immediate experimentation and initial operational use in the war against terrorism. A TBM based on Standard Missile could provide a range of 300 miles and be traded one-for-one for Tomahawks, and a TBM based on the GPS-guided multiple launch rocket system (GMLRS) could provide a range of 50 miles and be traded several for one.

(U) Submarines equipped with organic, AT3-equipped UAS and TBMs may provide the only way to perform DEAD in an access-constrained environment. They constitute the only potential source of DEAD capability that is as persistent as the airborne surveillance platforms in need of continuous protection, they are the only platform assured access in even the most contested littoral environment, and they are the only platform whose DEAD capability would itself be immune to the air defenses it would be attacking.

(U) In the sections which follow, the case for developing a submarine-based DEAD capability will be explored in greater detail. The following sections will describe the nature of the access denial problem, the key role of airborne surveillance, the problem of airborne sensor lockout, the characteristics of modern SAM systems, the origins of current approaches to DEAD, their limitations in an access-constrained environment, and close with an agenda for experimentation with and initial operational use of submarine-based AT3 networks and TBMs.

3 THE ACCESS DENIAL PROBLEM

(U) All fixed, non-hardened targets within a radius of 500 to 1000 miles of an advanced opponent have become vulnerable to conventional attack by precision-guided ballistic and cruise missiles. This vulnerability to over the horizon attack will extend to large ships at sea when over-the-horizon ocean surveillance and long range anti-ship ballistic missiles are deployed, as they are apparently about to be by China.

(U) GPS (and its Russian and Chinese counterparts) combined with modern, widely available inertial navigation systems (INS) have led to a quantum leap in conventional TBM capabilities, giving them the accuracy needed to attack point targets with unitary warheads and area targets with submunitions. Even single stage TBMs like the Chinese M series provide ranges of 300-600 km (185-375 miles) and payloads of 500 kg (1100 lbs). A precisely delivered 500 kg payload of simple submunitions like the M-77 grenade can destroy soft targets over a circular area of two million square feet centered at their point of release. TBMs like these, and their longer range cousins, could wreak havoc on airfields and ports within their range. For the purpose of this discussion, I will focus on airfield vulnerabilities.

(U) Airfields within range of opposing TBMs will be inherently vulnerable in the expeditionary environments typical of likely future air operations for four reasons. First, simply building the hardened shelters to protect, say, five 72 aircraft wings of tactical fighters is a major, multi-billion dollar investment that few potential allies are likely to make on their own. Second, in a world where the location of future conflicts is less predictable than it was during the Cold War, the U.S. will not be able to invest in hardening airfields in all the potential areas where it may be called on to fight. Third, even in cases where the U.S. did make this investment during the Cold War, as in Saudi Arabia, it still proved too expensive to provide shelter to the thousands of U.S. personnel which must live and work on the base; hence the enormous tent cities which were erected on base, which would remain a lucrative target even at the hardest base. Finally, it is simply impossible to provide hardened shelters for the various large, high value support aircraft which are integral to any expeditionary air operation, such as AWACS, JSTARS, Rivet Joint, KC-135 and KC-10 tankers, and airlifters like the C-5 and the C-17. For all these reasons, countries that deploy large mobile TBM forces will force their adversaries to avoid bases within 1000-1500 miles of their territory.

(U) This constraint will, at a minimum, reduce by half or more the sortie rate of a given size force of tactical aircraft, and increase the cost in terms of additional tanker support and bases for those tankers necessary to give that force the range to attack a given set of targets. Perhaps more important, there will be circumstances due to the political geography of a particular conflict in which the only bases potentially available will be within range of an opponent's missile force. This will lead to cases where land-based tactical aircraft will be denied access to a given theater altogether, until the threat to their bases has been suppressed or eliminated by other forces.

(U) Attempts are being made to extend this threat to naval forces on the surface. The technical challenges involved are significant, and this is not the venue for assessing them. What is clear is that there are potential solutions and the US needs to take this threat seriously. The crucial distinction is that the threat against ships presumes the survival and effective functioning of an OTH surveillance system, whereas the threat against land bases does not. The defeat of an opponent's ocean surveillance capabilities would be sufficient to enable access for ships on the surface. Unlike an opponent's land attack and antiship missiles, which are mobile, its ocean surveillance system would inevitably include some fixed nodes whose destruction would have that effect. Thus, one can imagine that access for surface ships might be regained without the need for persistent airborne surveillance, whereas regaining access to local bases ashore will.

4 THE KEY ROLE OF AIRBORNE SURVEILLANCE

(U) The surveillance challenge against an enemy's TBM forces in the field largely boils down to the problem of detecting vehicles. This is obviously a difficult problem, both because military vehicles are hard to distinguish from other vehicles, and because all vehicles are difficult if not impossible to detect from a distance if they are not moving, emitting a signal, or launching a weapon.

4.1 RADAR SURVEILLANCE

(U) Moving vehicles can be detected by MTI radars in all weather at ranges that depend on the altitude and aperture of the sensor. Future airborne surveillance platforms modeled on today's JSTARS, U-2, and Global Hawk will be able to detect targets out to 150 miles. On the other hand, faced with reasonably advanced air defenses, such platforms will likely need to standoff at least that far until those defenses are destroyed. The desire to escape this conundrum is one reason why the Department of Defense (DOD) has now tried twice to develop a space-based radar program. The fact that both these efforts failed is a sign of how difficult it will be to replace airborne surveillance platforms.

(U) In principle, a constellation of such satellites could be deployed that would provide continuous coverage of the earth within its orbital planes. Deployed in low orbit, such a constellation would need to include 20-40 satellites to ensure that one is always above the horizon. Alternatively, space-based radars could be deployed in medium orbits, like the GPS constellation, where many fewer satellites would provide continuous coverage, but where power/aperture products for the radars would need to be much greater.

(U) Obviously, in either case space-based radar was not going to be cheap, meaning that it would need to accommodate the requirements of both the Intelligence community and the DOD, but those requirements are very difficult to reconcile. The Intelligence community's prime interest was and remains in a system that provides continuous SAR imagery. DOD was most interested in continuous MTI radar coverage. A SAR satellite constellation could be implemented using medium orbits, whereas an MTI capability could only be deployed in low orbits. The compromise that always resulted led to a system with full SAR/MTI capability deployed in low orbit but in a constellation significantly smaller than that needed to provide continuous coverage in any one location.

4.2 SIGNALS INTELLIGENCE

(U) Vehicles can also be detected when they use a radio or a radar. SIGINT systems designed to detect these signals have longer detection ranges than radars because the signals they collect are more powerful, not having suffered the attenuation of a two way trip in which the power of the signal falls as the fourth power of the distance traveled. Thus, for example, airborne SIGINT collectors such as RC-135, EP-3, and Guardrail can always see further into contested air space than can airborne radars.

(U) At the same time, the signals that SIGINT sensors collect are often highly directional. This applies with special force to ELINT sensors that collect air defense radar signals. Since a radar's relatively narrow main beam sends out a much more powerful signal than do its sidelobes, and since that main beam is usually aimed at the horizon and scanned in azimuth more than in elevation, the probability of detecting the radar's signal can vary significantly depending

upon where the ELINT receiver is. Because of this, airborne ELINT sensors have a major advantage over satellite-based ELINT sensors when used in a tactical setting.

(U) An air defense radar's main beam will rarely be aimed directly at a satellite because the air defense radar will be oriented toward the horizon and low orbiting satellites quickly transit the horizon. This means that space-based ELINT systems must exploit a radar's sidelobes if they are to detect it and this is much more difficult than a main lobe detection. Unlike space-based radar, space-based ELINT satellites have played and will continue to play an important surveillance role, especially in ocean surveillance, where the radars in question are usually transmitting continuously, and where it is not necessary to insure a reliable detection on every pass. But airborne ELINT will remain necessary to insure detection of intermittent radar and communication signals.

5 MODERN AIR DEFENSES

(U) The Soviets and now the Russians developed four generations of long range radar-guided SAM systems, as represented by their numbers in the NATO numerical naming scheme. The first generation was the SAM 2/3 family (1950s, fixed, roughly 20 mile range); the second was the SAM 5/6 (1960s, fixed 100 mile range and mobile 20 mile range); the third was the SAM 10/12 (1980s, mobile, 100 mile range; and the fourth being today's modernized and even longer-ranged versions of the third generation, known as the SAM 21 or the SAM 400, which may also be combined with "passive," multistatic radar and ELINT (ground-based AT3) surveillance systems.

(U) The third and fourth generation systems use modern phased array antennas for both low frequency surveillance and higher frequency engagement radars; high acceleration and long range rockets; a capacity for tracking many targets simultaneously; active terminal seekers that enable a multi-shot fire and forget capability; and the ability under many circumstances to break down and relocate quickly after an engagement. For simplicity one can refer to the first two generations as "single digit" SAMs and the more modern systems as "double digit" SAMs. It is an often ignored fact that no western air force has ever faced double digit SAMs in combat. In other words, all the air combat waged since the end of the Cold War has been waged against air defense systems which were initially developed no later than the late 1960s.

(U) As with advanced western air defense systems such as Patriot or Aegis, the engagement radars in double digit SAM systems no longer need to illuminate their targets continuously in order for their missiles to guide properly to their targets. In fact, a SAM-21 engagement radar might need only transmit half a dozen times for only a few seconds at a time during missile flyout until the missile's active seeker is ready to take over and finish the engagement.

(U) As if not more important, the source of a force's DEAD capability must be as persistent as the assets that must be protected. Here is where it starts to become important to understand the order of magnitude improvement in capability that double digit SAMs provide.

(U) When a SAM battery has a range of only 20 miles one can afford a situation in which it is suppressed only when a strike package is within range of it, because the degree of air space denial such a system otherwise provides is limited. When a SAM battery has a 200 mile range the air space it denies is sufficient to keep out the full panoply of the U.S.'s airborne surveillance assets. Currently planned approaches to destroying opposing air defenses assume a cooperative adversary. It is necessary to review a little of the history of suppressing and destroying enemy air defenses to understand exactly what this means.

6 THE PAST, PRESENT, AND FUTURE OF COUNTERING SAMs

(U) The original concept of operations for dealing with SAMs was developed during Vietnam. At its heart was the anti-radiation missile (ARM) which was designed to home on the SAM's engagement radars and the concept came to be known as suppressing enemy air defenses (SEAD). Vietnam was the first conventional conflict in which air forces had to deal with the challenge of repeatedly penetrating dense networks of radar-guided SAM defenses. The SEAD approach to countering SAM batteries was to jam their surveillance radars and force the batteries to use their engagement radars for surveillance in addition to fire control. Used continuously in this way, the engagement radars became vulnerable to strikes by air-launched ARMs which would home on the engagement radar and destroy it, or force it to shut down, thereby eliminating the battery's ability to guide its missiles. In the latter case, the battery was only temporarily disabled, but if the ARM shots were timed appropriately, accompanying packages of strike aircraft could pass through the air defense screen unmolested during the brief period the radars were off.

(U) These tactics were developed when SAM batteries and their radars were fixed targets. Thus their location and frequency could be determined in advance and ARMs could be set to home on specific radars before takeoff. Using this mode of operation, the ARMs did not need precise geographic coordinates for the radars in order to be effective; just their operating frequency and a rough location. This was fortunate because the ELINT intelligence aircraft and satellites which were used to identify and locate them did not have the ability to do so with precision.

(U) Another key benefit of the fact that the SAM batteries did not move was that ARMs could be put in the air over the batteries known location in advance of a strike package's arrival, whether the engagement radar was on or not. Launching ARMs preemptively was and is important because SAMs generally fly faster than ARMs and would arrive at the strike package before the SAMs' engagement radar had been destroyed if the ARMs were launched in a purely reactive mode. In air-to-air parlance, SAMs always have a substantial F-Pole or A-Pole

advantage against a reactively-launched ARM so even with modern high speed ARMs (HARMs) the defense suppressor usually has to shoot first.

(U) Variations on this concept were used by the Israelis in the 1973 war and later in Lebanon, and by the U.S. again in both the first Gulf War and in the war over Kosovo. Loss rates for allied strike aircraft protected by SEAD aircraft in these conflicts have steadily fallen, from as much as 5% to essentially nil. This would appear to be a good news story but the truth is a little more complicated.

6.1 SEAD REQUIRES A COOPERATIVE ADVERSARY

(U) First, there has been a steadily widening gap since Vietnam and the Yom Kippur war between the capabilities of the best SAM systems available and the capabilities of the actual systems faced in Israel's wars in Lebanon and the U.S.'s wars in Desert Storm, Kosovo, and Operations Allied Force and Iraqi Freedom. Western defense suppression methods have steadily improved while opposing air defenses have remained static or regressed in capability.

(U) The second problem with the SEAD approach is that even given the relative technical backwardness of the air defense systems that the U.S. has faced, used skillfully they can still be operated in such a way as to sharply limit the effectiveness of our air forces. The war in Kosovo against SAM-2s, 3s, and 6s – the same single digit SAM systems that the Israelis faced in the Yom Kippur War more than 25 years earlier – is the best example of this problem. The Serbians were able to preserve their air defense systems as a kind of threat in being, meaning that NATO air forces never gained the total air supremacy that they did in the first Gulf War against Iraq, an opponent that was arguably better equipped, but whose air defense crews were less well-trained. Instead, NATO air operations were limited through to the end of the war by the need to escort every strike package with the full panoply of defense suppression assets; assets which had become scarce after the perceived success of Desert Storm.

(U) The essence of the SEAD approach is to create a game of chicken between a HARM that is already in the air, and a SAM engagement radar that is illuminating an airborne target in order to guide a SAM to it. If the HARM is launched at the right moment and place, the engagement radar will face a choice between completing the engagement and risking destruction, and shutting down to deny the HARM a signal to home on, causing it to “go silly,” but also denying a guidance signal to its SAM, causing it to go silly as well. In neither case does the SAM battery succeed in destroying its target, but in the latter case, the SAM battery's capabilities are only suppressed temporarily, and the whole process must be repeated again for every strike sortie that is launched.

(U) Basically, Iraqi air defense crews chose the first approach, while their Serbian counterparts chose the latter. Thus, in Desert Storm, Iraqi air defense radars died en masse in the first days of the air war, and their SAM batteries became ineffective, whereas Serbian SAM batteries retained their potential throughout the months long campaign over Kosovo.

6.2 SEAD ASSETS MUST BE AS PLENTIFUL AS THE FORCES THEY PROTECT

(U) In order to create and make viable this game of chicken a panoply of specialized defense suppression assets are needed to escort incoming strike aircraft. In addition to the HARM shooters, penetrating jammers are needed to blind surveillance radars and force engagement radars to play that role and emit continuously, thereby exposing them to the HARMs. In cases where the air defense systems are integrated so that radars from adjoining batteries can support each other, their data links must be jammed by specialized low band communications jamming aircraft. Finally, the ELINT needed both to provide HARMs with the location and frequency of their targets, as well as alerts that those targets have gone active require specialized ELINT aircraft.

(U) Thus, a strike by half a dozen F-16s might also require escort by other F-16s with a special HARM Targeting System (HTS) pod that allows it to target HARMs against specific emitters, EA-6B penetrating jammers, EC-130 Compass Call communications jammers, and RC-135 ELINT aircraft. Combined with an F-15C escort if there is an extent air-to-air threat, and the fact that all of the tactical aircraft listed above will likely need air refueling at least once during a sortie, one can begin to see the overhead that is required to sustain operations against SAM batteries that act as a force in being by using shut down tactics and mobility.

(U) The problem becomes more acute when one looks at how investment decisions were made regarding these specialized defense suppression assets after the positive experience of Desert Storm. In the early 1990s the Air Force divested itself of its force of F-4G Wild Weasel HARM shooters and EF-111 penetrating jammers, substituting for the former with the much less capable HTS pod and not substituting for the latter at all. The logic behind these decisions was that future opponents would behave like the Iraqis and expose themselves to the U.S. SEAD approach, and more importantly, that the whole issue of SEAD would soon be mute because stealth aircraft like the F-117, the B-2, and the F-22 would simply make radar-guided air defenses obsolete. The result was to make the availability of scarce SEAD assets the pacing item for allied air operations throughout the war in Kosovo.

6.3 THE EMERGENCE OF DEAD

(U) This experience led both the Air Force and the Navy to reconsider their approach to SEAD, and out of this review emerged a new concept that sought the destruction rather than the mere suppression of enemy air defenses. The Air Force and the Navy have emphasized different approaches to DEAD, but both have in common the basic concept that a SAM engagement radar should not be able to survive an engagement in which it emits, even if the emission is brief.

(U) The Air Force has embraced AT3 and precision ELINT as a means of making standoff, GPS-guided weapons potential radar killers. AT3 will be deployed first as an upgrade to the F-16's HTS pod, and later as an upgrade to the radar warning receivers on all F-16s. The

Navy has instead focused on improving the HARM missile; first by adding GPS guidance to it; second, by giving it the ability to directly receive offboard ELINT broadcasts; third, by giving it the ability to take additional in flight bearing measurements as long as the threat radar continues to emit to further reduce target location error (TLE); and fourth, by adding an active, millimeter wave (MMW) terminal seeker to detect an home on the radar vehicle if it shuts down.

(U) Moving forward, either of these two approaches would likely defeat the “shut down and move” tactics used by the Serbs in Kosovo using first and second generation SAM systems. As for double digit SAMs, the assumption seems to be that these same DEAD tactics and technologies will simply be migrated to stealthy F-22s and/or F-35s.

THE LIMITS OF TACAIR AS A SOURCE OF DEAD

(U) Leaving aside the details of adapting DEAD to F-22 and F-35 (it is unclear how many F-22s will be capable of AT3 because of data link issues and under current plans neither aircraft will have a fast weapon like HARM that it can carry internally), there are more basic problems with using tactical aircraft as DEAD assets against double digit SAMs.

(U) For example, there are only two air bases within 1500 miles of Taiwan that U.S. tactical aircraft currently have access to. Both would require Japanese permission to use in the event of war and neither is hardened against conventional ballistic or cruise missile attack. Even when used to full capacity, it is not clear they can support the number of sorties needed simply to defend Taiwanese air space from conventional air attack. The analyses assessing this issue have not factored in the effect of sea-based tactical air, but of course there will be access issues within a 1500 mile radius of China for aircraft carriers as well if anti-ship ballistic missiles are deployed.

(U) In short, an approach to DEAD based on stealthy tacair will be neither persistent nor large. Instead, it will come and go, perhaps escorting equally small numbers of strike aircraft, and provide only a fleeting presence over the battlefield. For such an approach to be effective it would require that the opposing SAM batteries act more like the Iraqis did in Desert Storm than the Serbs did in Operation Allied Force.

7 THE CENTRALITY OF AT3 TO DEAD FROM UNDER THE SEA

(U) Double digit SAM engagement radars must be destroyed whenever they emit simply in order to enable persistent airborne surveillance, but this becomes a significant problem when airborne surveillance is itself necessary to provide the persistent AT3 needed to perform DEAD. The same logic obviously applies to the source of fast weapons needed to prosecute AT3



contacts. How to deploy them in persistent fashion within roughly 200 miles of their targets if the surface and the air are off limits to traditional sensor and weapon platforms?

7.1 THE LIMITS OF TRADITIONAL ELINT

(U) The key is to create AT3 networks using nodes designed from the start to exploit T/FDOA. One of the major advantages of a network using T/FDOA is that the passive receive antennas do not need high angular resolution and can therefore be deployed on the smallest of sensing platforms. This was not always the case.

(U) TDOA and FDOA signal processing techniques have been used for years to reduce the inherent target location error (TLE) that occurs with traditional angle-of-arrival (AOA) techniques, and also to locate very short or “burst” transmissions. TLE using AOA techniques against RF emitters is relatively high because RF receive antennas have relatively low angular resolution. Thus, they can only measure the angle of arrival of an incoming signal to an accuracy of one or two degrees, which depending on the range will generate target bearing inaccuracies of 100s to 1000s of feet. Even when multiple bearings are taken over a relatively long baseline, such as those created as a satellite flies over an emitter or a patrolling aircraft flies alongside it, the resulting target location error ellipse always remains substantially larger than what is required to target a GPS-guided weapon, and gets worse with additional standoff range. Furthermore, TLE becomes essentially infinite when the emitter emits only in short bursts and moves frequently, thereby eliminating any baseline for multiple AOA bearings.

7.2 THE VALUE OF PURE T/FDOA NETWORKS

(U) The fundamental constraint on ELINT-derived TLE using AOA methods is the limit on bearing accuracy. T/FDOA networks get around this constraint by measuring the precise time of arrival and/or frequency of the same signal at two or three different locations. The most common method is a pure TDOA approach that measures the signal’s time of arrival at three separate locations. This results in three separate pairs of time of arrival measurements, each of which forms a hyperbola on the earth’s surface along which the emitter must lie. Any two pairs will form two separate hyperbolas that intersect at two precise locations, and the third pair is used to choose between those two points.

(U) A variation on the pure TDOA approach combines the time difference of arrival measurement at each receiver with a measurement of the precise frequency of the signal. As long as the emitter is fixed and at least one of a pair of receivers is moving relative to it, and thereby generating a Doppler shift, the received signal’s frequency will vary at each receiver and the difference in frequency will determine a line of possible locations for the emitter that could have produced that difference. Combined with a TDOA measurement by the same pair of receivers, a single precise location for the emitter can be derived.

(U) T/FDOA signal processing is inherently computationally intensive, and this intensity scales with the complexity and density of the signal environment, which in the past required large data processing facilities and long computation periods. Also, the geometry of the receivers relative to the emitter affects geo-location accuracy. The ideal geometry is to surround the

emitter with receivers but in practice this is obviously not always possible. For example, if the receivers are on two platforms standing off some distance from an emitter and in roughly the same direction, they will form a line normal to the emitter rather than a circle surrounding it and this will reduce accuracy enough to prevent targeting a coordinate-seeking weapon, though the resulting accuracy will still be significantly better than that possible in the same situation using AOA methods.

(U) For these reasons and others, this method of locating emitters was first exploited for ground-based, HF/DF systems by the intelligence community, where neither time nor very precise location were of the essence and the cost and size of primitive computing systems were not a problem.

7.3 THE ARRIVAL OF TACTICAL T/FDOA

(U) The Army's Guardrail system was the first DOD system to use T/FDOA on the battlefield. Guardrail is a Corps level airborne SIGINT asset based on the RC-12 aircraft which was originally designed to use AOA techniques, with a focus on lower frequency communications intelligence (COMINT) signals rather than ELINT. An upgrade to Guardrail in 1991 gave it T/FDOA capabilities, but even at that relatively late date it initially needed to use AOA techniques to "cue" the TDOA processor to reduce the computational requirements and produce a timely result. At about the same time, DARPA AT3 with the goal of producing a T/FDOA capability from scratch that fully exploited modern information processing technologies, used existing data links, and relied on small, relatively unsophisticated receive antennas that could be deployed on any tactical platform.

(U) AT3's goals were to demonstrate TLE of less than 50 meters using receivers that were 50 miles away within 10 seconds of the emitter's activation. AT3 was considered a success and an operational application using existing digital radar warning receivers (RWRs) on F-16s is being implemented by the Air Force. At the same time, the Net-Centric Collaborative Targeting (NCCT) program has demonstrated an upgrade to other existing airborne ELINT and COMINT systems like RC-135, U-2, and EP-3 that allows them to form ad hoc T/FDOA networks among themselves and with Guardrail. The execution of AT3 and NCCT has already greatly expanded DOD's ability to do precision ELINT, and the planned spread of this capability to high altitude long endurance (HALE) UAS like Global Hawk will increase the global reach and persistence of this capability, but all the platforms in question are relatively expensive, multipurpose assets which will not always be available at all, or in the numbers necessary to form a TDOA network. And none of them are stealthy, which means that they would need to stand well off from defended air space, enough to negatively impact the accuracy achievable even using the TDOA method.

8 A SUBMARINE-BASED APPROACH TO DEAD

(U) Fortunately, the AT3 approach to precision SIGINT targeting can be implemented without penalty on even small, tactical UAS with some additional development. The utility of small UAS in the war on terror has already been demonstrated, where their ubiquity, endurance, and streaming video output can be used to provide persistent optical surveillance without alerting the opponent. Combined with the Precision Strike System - Special Operations Force (PSS-SOF) imagery targeting algorithm, they will soon be able to provide very precise coordinates to support time critical strikes by GPS-guided weapons.

(U) Implementing AT3 on small UAS would have obvious potential in the war on terror in the COMINT realm, but in the longer term, it could also play a key role in providing the precision ELINT targeting necessary for the destruction rather than mere suppression of advanced air defense systems.

(U) The key advantage of a marriage between small UAS and AT3 is that the latter turns the size and aperture limitations of the former from a vice into a virtue. Small size and low speeds make small UAS inherently stealthy, not just because of their low cross section but also because they naturally blend into the clutter background along the radar horizon. This means that they can operate covertly and persistently at close range to their prey and in networks that approximate the optimum geometry for a T/FDOA targeting solution.

(U) Persistence and stealth for networks of small UAS would be optimized if the UAS can be launched close to their target and operated using low probability of intercept (LPI) data links. Here is where a key role emerges for the submarine, as both the source of the UAS, as the only platform able to command and control them using low powered, stealthy data links, and as the only persistent source of fast weapons to prosecute the targets they locate.

9 AN AGENDA FOR EXPERIMENTATION

(U) I will close by describing several issues to explore by the submarine force in a program of experimentation with AT3 networks using small UAS and fast, coordinate seeking weapons.

(U) First, there are tradeoffs that must be addressed regarding the number of nodes used in the network. A three node network is necessary for a pure TDOA approach, whereas a two node network is sufficient for a combined T/FDOA approach. The fewer the nodes the better but implementing a two node T/FDOA network requires that at least one of the nodes be moving relative to the emitter of interest at a velocity sufficient to generate an exploitable doppler

differential between the two receivers. The minimum size of that differential needs to be explored because the lower the relative velocity between the UAS and the target radar the easier it will be to maintain the former's stealth.

(U) Second, there is the possibility that one of the nodes in the AT3 network could be the mother submarine's electronic support measures (ESM) mast. The obvious attraction of this mode of operation is that the submarine need only maintain one UAS orbit in order to create a fully functional T/FDOA network. This would be beneficial both in simplifying command and control and in essentially doubling the persistence of a given payload of UAS assuming that they are not recovered after use. Data would need to be collected on how SAM battery location affects the required submarine operating area if it is to ensure reception of radar signals by an organic ESM mast.

(U) This concept of operation raises the additional question of a split mode of operation whereby one submarine operates closer inshore and manages the ELINT network while another stands back and provides the persistent source of prompt firepower. The advantage of such a mode of operation would be to allow the submarine that must expose itself by firing a weapon to stand off further, but this implies a covert means of communication between the separate submarines. Experiments would illuminate how much the required message traffic could be reduced to levels that would allow the use of existing means of covert communication such as EHF satellite communications, or whether a UAS being used as an AT3 node could also serve as a communication relay.

(U) Finally, with regard to fast, coordinate-seeking weapons, the mobile target kill chain often requires that they be deployed close enough to their targets such that those targets can be struck promptly enough to be treated as if they were fixed targets. Fast, coordinate seeking weapons could also be provided with the ability to home on moving targets that are in the process of clearing a datum, much as we expect double digit SAM batteries to shuffle their radars' positions after an engagement. This could have the effect of relaxing the time urgency of most mobile target engagements. Existing TBMs and smart sub-munitions such as sensor-fuzed weapon (SFW) could be combined to experiment with such a concept.



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