Kosovo and the Continuing SEAD Challenge

Just as the attacks of 11 September 2001 refocused national attention on terrorism, so did the shootdown of an F-117 stealth aircraft over Kosovo in 1999 serve as a wake-up call for the Air Force to improve tactics, techniques, and procedures relating to the suppression of enemy air defences

By Dr Benjamin S Lambeth

Almost everyone acknowledged that the allied forces' use of airpower in the North Atlantic Treaty Organisation's (NATO) air war for Kosovo in 1999 was a resounding success.[1] Yet, some troubling questions arose well before the war's favourable outcome over a number of unexpected problems along the way. Perhaps the most disturbing of these involved assessed deficiencies in the suppression of enemy air defenses (SEAD) in support of allied strike operations against the enemy's fixed and mobile targets.

Much of the surprise experienced by allied aircrews during their early, unsuccessful forays against Serbia's integrated air defence system (IADS) in Operation Allied Force may have stemmed from an overconfidence in the Air Force's SEAD capability, which had taken root in the aftermath of the highly effective SEAD campaign during the opening days of Operation Desert Storm eight years before. At that time, Baghdad was protected by the heaviest concentration of air defenses of any city in the world after Moscow. Likewise, highly internetted, radar-guided surface-to-air missiles (SAM) and antiaircraft artillery (AAA) proliferated throughout the rest of Iraq. Accordingly, the coalitions initial SEAD attacks focused on neutralising Iraq's radar-directed medium- and high-altitude SAMs with AGM-88 high-speed anti – radiation missiles (HARM) so as to open up a sanctuary for coalition aircraft above 10,000 feet[2] The underlying

concept of operations entailed using a combination of tactical surprise and deception, from the very first moments of the campaign, to force the largest possible number of Iraqi SAM batteries to disclose their positions to the coalitions HARM shooters by activating their radars.[3]

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During the first four hours of the war, coalition sensors logged nearly 100 radar emissions from Iraqi air defenses, resulting in the firing of more than 500 HARMs to useful effect during the first 24 hours. Consequently, Iraq's IADS operators quickly learned that activating their radars meant inviting a deadly attack. By the sixth day of the war, Iraqi SAM, AAA, and early warning radar emissions had dropped by 95 percent. Now that Iraq's air defenders were fully intimidated and loath to activate their SAM acquisition-and-tracking radars, coalition SEAD operations moved from suppression to the physical destruction of enemy defences, using general-purpose bombs, AGM-65 Maverick missiles, and CBU-87 cluster bombs.[4] Instead of rolling back the enemy's defences sequentially, coalition planners attacked those assets simultaneously, neutralising them in such a way that Iraq never recovered. For good reason, the US Air Force's Gulf War Air Power Survey later characterised the SEAD campaign as 'one of the clear success stories' of the war [5].

In marked contrast to the highly satisfying SEAD experience of Desert Storm, the initial effort to suppress Serbian air defences in Allied Force did not go nearly as well as expected. The avowed objective called for neutralising as many of Serbia's SAMs and AAA sites as possible, particularly its estimated 16 SA-3 Low Blow and 25 SA-6 Straight Flush fire-control radars. Another early goal involved taking out or suppressing long-range surveillance radars that could provide timely threat warnings to enemy troops carrying shoulder-fired, infrared SAMs such as the SA-7. Unlike the Iraqis, however, the Serbs kept their SAMs defensively dispersed and operating in an emission-control mode, prompting concern that they meant to draw NATO aircraft down to lower altitudes for easier engagement. Before the initial strikes, there were reports of a large-scale dispersal of SA-3 and SA-6 batteries from nearly all of the known garrisons. The understandable reluctance of enemy SAM operators to emit and thus render themselves cooperative targets made them much harder to find and attack, forcing allied aircrews to remain constantly alert to the radar-guided SAM threat throughout the war.[6] This situation also had the effect of denying some high-risk targets for a time, increasing force-package size, and increasing overall requirements for SEAD sorties.

Moreover, unlike the more permissive operating environment in Desert Storm, limitations to airspace availability typically made for high predictability on the part of attacking NATO aircraft, and prohibitions against collateral damage frequently prevented the use of the most tactically advantageous attack headings. Adm Leighton Smith, USN, retired, commander of NATO forces in Bosnia from 1994 to 1996, said that the resulting efforts to neutralise the Serb IADS were 'like digging out potatoes one at a time.'[7] Gen John Jumper, commander of United States Air Forces in Europe (USAFE) at the time, later added that the combined air operations centre (CAOC) could never get political clearance from NATO to attack the most troublesome early warning radars in Montenegro, which meant that the Serbs knew when attacks were coming most of the time.[8] In other cases, the cumbersome command and control (C2) arrangements and the need for prior CAOC approval before attacking the fleeting IADS pop-up targets resulted in many lost opportunities and few hard kills of enemy SAM sites.

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THE ALLIED FORCE GAME PLAN

Allied Force drew principally on 48 Air Force Block 50 F-16CJs and 30 Navy and Marine Corps EA-6B Prowlers to conduct the suppression portion of allied counter-SAM operations. Land-based Marine EA-6Bs, tied directly to attacking strike packages, typically provided electronic countermeasures (ECM) support for missions conducted by US aircraft. Navy Prowlers aboard the USS Theodore Roosevelt supported carrier-launched F-14 and F/A-18 raids and strike operations by allied fighters. Each of the carrier-based Prowlers carried two HARMs. In contrast, those operating out of Aviano Air Base, Italy, almost never carried even a single HARM, preferring to load an extra fuel tank because of their longer route to target. To compensate, EA-6Bs often teamed with HARM-shooting F-16CJs or with HARM-equipped German and Italian Tornado electronic-combat- role variants.[9]

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The Air Force used EC-130 Compass Call electronic warfare (EW) aircraft to intercept and jam enemy voice communications, thus allowing the EA-6Bs to concentrate exclusively on jamming the enemy's early warning radars. RC-135 Rivet Joint electronic intelligence (ELINT) aircraft, which orbited at a safe distance from the combat area, validated the success of the latter efforts. The biggest problem with the EA-6B was its relatively slow flying speed, which prevented it from keeping up with ingressing strike aircraft and diminished its jamming effectiveness. On occasion, the jamming of early warning radars forced Serb SAM operators to activate their fire-control radars, which, in turn, rendered them susceptible to attack by a HARM. Accordingly, the enemy limited activation of his SAM fire-control radars to increase their survivability.[10]

SEAD operations conducted by F-16CJs almost invariably entailed four-ship formations, the spacing of which ensured that the first two aircraft in the flight always looked at a threat area from one side while the other two monitored it from the opposite side. That enabled the aircraft's HARM Targeting System, which provided only a 180-degree field of view in the forward sector, to maintain 100 percent sensor coverage of a target area whenever allied strike aircraft attempted to bomb specific aiming points within it. According to one squadron commander, the F-16CJs would arrive in the target area ahead of the strikers and build up the threat picture before those aircraft got close, so that the strikers could adjust their ingress routes accordingly. In so doing, the F-16CJs provided both the electronic order of battle and the air-to-air threat picture as necessary. The squadron commander added that enemy SAM operators got better at exploiting their systems at about the same rate the F-16CJ pilots did, resulting in a continuous cat-and-mouse game that made classic SAM kills 'hard to come by.'[11]

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Evidently, the Serbs launched only a few SAMs against attacking NATO aircraft the first night. The second night, the enemy fired fewer than 10 SA-6s, none of them scoring a hit. Later during Allied Force, the Serbs frequently fired SAMs in large numbers, with dozens launched in salvo fashion on some nights but only a few launched on others. Although these ballistic launches constituted more a harassment factor than any serious challenge to NATO operations, in numerous instances allied pilots had to jettison their fuel tanks, dispense chaff, and manoeuvre violently to evade enemy SAMs that were guiding.[12]

Indeed, the SAM threat to NATO's aircrews proved far more pronounced and harrowing than media coverage typically depicted, and aggressive jinking and countermanoeuvring against airborne SAMs frequently became necessary whenever the Serbs sought to engage NATO aircraft. Ten or more pilots operating in a target area might report a SAM shot as ballistic while the one pilot on whose helmet the missile was figuratively guiding would be actively reacting to it. Shortly thereafter, 10 pilots would recover to widely dispersed home bases and report nonthreatening ballistic launches, while only one would return with the evidence of a guided shot. Such episodes drove an initial impression among Allied Force leaders that 'most' of the observed SAM shots were ballistic. Fusion of all the pertinent information and elimination of duplicate reporting, however, indicated that a substantial number of SAM launches, perhaps as many as a third, were guided.[13]

Indeed, Gen Wesley Clark, US Army, supreme allied commander, Europe (SACEUR), later reported numerous instances of near-misses involving enemy SAM launches against NATO aircraft. General

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Jumper added that a simple look at cockpit-display videotapes would show that 'those duels were not trivial.'[14] From the very start of NATO's air attacks, Serb air defenders also sought to sucker NATO aircrews down to lower altitude to bring them within the lethal envelopes of widely proliferated man-portable air defence systems (MANPADS) and AAA emplacements. A common Serb tactic involved firing on the last aircraft in a departing strike formation, perhaps on the presumption that those aircraft would be unprotected by other fighters; flown by less experienced pilots; and low on fuel, which would limit their freedom to countermanoeuvre.

THE F-117 SHOOTDOWN

It did not take long for the problems connected with the air war's SEAD effort to register their first toll. On the fourth night of air operations, an apparent barrage of SA-3s downed an F-117 at approximately 2045 over hilly terrain near Budanovci, about 28 miles north-west of Belgrade – marking the first combat loss ever of a stealth aircraft. Fortunately, the pilot ejected safely and, against formidable odds, was recovered before dawn the next day by a combat search and rescue team using MH-53 Pave Low and MH-60 Pave Hawk helicopters led by a flight of A-10s.

Afterward, this unexpected event occasioned a flurry of speculation regarding how it might have taken place. Experts at Lockheed Martin Corporation, the aircraft's manufacturer, reported that – unlike earlier instances of F-117 combat operations – the

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Remains of downed F-117

missions flown over Yugoslavia required the aircraft to operate in ways that may have compromised its stealthy characteristics. By way of example, they noted that even a standard turning manoeuvre could increase the aircraft's radar cross section by a factor of 100 or more. Such turns were unavoidable in the constricted airspace within which the F-117s had to fly.[15] Another unconfirmed report suggested that the RC-135 Rivet Joint aircraft monitoring enemy SAM activity may have failed to locate the SA-3 battery thought to have downed the F-117 and may not have relayed timely indications of enemy SAM activity to the appropriate C2 authorities. Lending credence to that interpretation, Gen Richard Hawley, commander of Air Combat Command at the time, commented that 'when you have a lot of unlocated threats, you are at risk even in a stealth airplane.'[16]

Although the Air Force has remained understandably silent about the confluence of events it believes occasioned the F-117's downing according to press reports, Air Force assessors concluded, after conducting a formal postmortem, that a lucky combination of low-technology tactics, rapid learning, and astute improvisation had converged in one fleeting instant to enable an SA-3 not operating in its normal, radar-guided mode to down the aircraft. Undoubtedly, enemy spotters in Italy reported the aircraft's take off from Aviano, and IADS operators in Serbia, as well as those in Bosnia and along the Montenegrin coast, could have assembled enough glimpses of its position enroute to its target from scattered radars to cue a SAM battery near Belgrade to fire at the appropriate moment. The aircraft had already dropped one laser-guided bomb (LGB) near Belgrade, offering the now-alerted air defenders yet another clue. (The Air Force is said to have ruled out theories hinging on a stuck weapons-bay door, a descent to below 15,000 feet, or a hit by AAA.)[17]

Allegedly, at least three procedural errors contributed to the downing.[18] First, ELINT collectors reportedly could not track the changing location of the three or four offending SAM batteries. Three low-frequency Serb radars that could have detected the F-117's presence, at least theoretically, were not neutralised because US strike aircraft had earlier bombed the wrong aiming points within the radar complexes. Also, F-16CJs carrying HARMs and operating in adjacent airspace could have deterred the SA-3 battery from emitting, but those aircraft had been recalled before the F-117 shootdown.

The second alleged procedural error entailed an EA-6B support jammer that was operating too far away from the F-117 (80 to 100 miles) to offer much protection. Furthermore, it was out of proper alignment with the offending threat radars, resulting in inefficient jamming.

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Last, F-117s operating out of Aviano had previously flown along more or less the same transit routes for four nights in a row (because of SACEUR's ban on overflight of Bosnia) to avoid jeopardising the Dayton Accords. That would have made their approach pattern into Yugoslav airspace predictable. Knowing the direction the F-117s would take, Serb air defenders could have employed low-frequency radars for the best chance of getting a snap look at the aircraft. Former F-117 pilots and several industry experts acknowledged that the aircraft is detectable by such radars when viewed from the side or directly below. US officials also suggested that the Serbs may have gotten brief, nightly radar hits while the aircraft's weapons bay doors opened fleetingly.

In the immediate aftermath of the shootdown, heated arguments arose in Washington and elsewhere over whether US European Command had erred in not acting aggressively to destroy the wreckage of the downed F-117 in order to keep its valuable technology out of unfriendly hands and eliminate its propaganda value, which the Serbs made every effort to exploit.[19] Said Gen John M. Loh, USAF, retired, former commander of Tactical Air Command, 'I'm surprised we didn't bomb it, because the standing procedure has always been that when you lose something of real or perceived value – in this case real technology, stealth – you destroy it.'[20] Paul Kaminski, the Pentagon's former acquisition chief and the Air Force's first F-117 program manager during the 1970s, bolstered the case for at least trying to deny the enemy the wreckage. He noted that, although the F-117 had been operational for 15 years, 'there are

things in that airplane, while they may not be leading technologies today in the United States, [that] are certainly ahead of what some potential adversaries have.' Kaminski added that the main concern was not that any exploitation of the F-117's low-observable technology would enable an enemy to put the F-117 at greater risk but that it could help him eventually develop his own stealth technology in due course.[21] Reports indicated that military officials had at first considered attempting to destroy the wreckage but opted in the end not to follow through because they could not have located it before civilians and the media surrounded it.[22] Those issues aside, whatever the precise explanation for the downing, it meant not only the loss of a key US combat aircraft, but also the dimming of the F-117's former aura of invincibility, which for years had carried incalculable psychological value.

OTHER FRUSTRATIONS

The persistence of a credible SAM threat throughout the Kosovo air war meant that NATO had to dedicate a larger-than-usual number of strike sorties to the SEAD mission to ensure reasonable freedom to operate in enemy airspace. Thus, fewer sorties were available for NATO mission planners to allocate against enemy military and infrastructure targets although the limited number of approved targets at any one time tended to minimise the practical effects of that consequence. Moreover, the Block 50 F-16CJ, which lacked the ability to carry the LANTIRN targeting pod, was never used for precision bombing at night because it could not self-designate targets.[23]

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One of the biggest problems that confronted attacking NATO aircrews on defence-suppression missions was target location. Because of Kosovo's mountainous terrain, the moving-target indicator and synthetic aperture radar aboard the E-8 joint surveillance, target attack radar system (JSTARS) aircraft could not detect targets masked from view at oblique look angles, although sensors carried by the U-2 and the EC-135 Rivet Joint often compensated for this shortfall. The cover provided to enemy air defence assets by the interspersed mountains and valleys became a severe, complicating factor. Mitigating that constraint somewhat, the limited surveillance range of JSTARS caused by interposed ridgelines restricted E-8 operations primarily with regard to Kosovo, which harboured only a limited SAM threat (only one of the five SA-6 regiments and no SA-2s or SA-3s). Most of the enemy IADS targets lay outside Kosovo. Moreover, the U-2 and Rivet Joint typically performed well and did not suffer the same problems that sometimes plagued the E-8.[24]

By the same token, the Yugoslav IADS's extensive network of underground command sites, buried land-lines, and mobile communications centres hampered the allied effort to attack that system's internetted communications links. This internetting used fused radar input, which allowed the acquisition and tracking of NATO aircraft from the north, and subsequently fed the resulting surveillance data to air defence radars in the south. This enabled the southern sector operations centre to cue defensive weapons (including shoulder-fired man-portable SAMs and AAA positions) at other locations in the country that had no active radar nearby. That may have accounted, at least in part, for why the F-16CJ and EA-6B often proved ineffective as SAM killers since both employed the HARM to home in on enemy radars that normally operated in proximity to SAM batteries.[25] In all, well over half of the HARM shots taken by allied SEAD air-crews were preemptive targeting or so-called PET shots, with a substantial number of these occurring in the immediate area of Belgrade.[26] Many HARM shots, however, were reactive rather than preplanned, made in response to transitory radar emissions as detected.[27]

Yugoslavia's poorly developed road network outside urban areas also may have worked to the benefit of NATO attackers on more than a few occasions because the enemy's SAM operators depended on road transportation for mobility, and towed AAA tended to bog down when it left prepared surfaces and moved into open terrain. NATO pilots, therefore, studiously avoided flying down roads and crossed them when necessary at 90-degree angles to minimise their exposure time. By remaining at least five kilometres from the nearest road, they often negated the AAA threat, albeit at the cost of making it harder to spot moving military vehicles.

Whenever available intelligence permitted, the preferred offensive tactic entailed destruction of enemy air defenses (DEAD) attacks aimed at achieving hard kills against enemy SAM sites using Block 40 F-16CGs and F-15Es carrying LGBs, cluster bombs, and the powered AGM-130, rather than merely suppressing SAM radar activity with F-16CJs and HARMs.[28] For attempted DEAD attacks, F-16CGs and F-15Es would loiter on call near tankers orbiting over the Adriatic, rolling in on any pop-up SAM threats that might suddenly materialise.[29] Also, the unpowered AGM-154 Joint Standoff Weapon (JSOW), a near-precision glide weapon featuring inertial and Global Positioning System satellite guidance and employed by Navy F/A-18s, used its combined-effects submunitions to good effect on at least a few occasions against enemy acquisition-and-tracking radars.[30]

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One problem with such DEAD attempts was that the data cycle time had to be short enough for attackers to catch the emitting radars before they moved on to new locations. One informed report observed that supporting F-16CJs were relatively ineffective in the reactive SEAD mode because the time required for them to detect an impending launch and get off a timely HARM shot to protect a striker invariably exceeded the flyout time of the SAM aimed at the targeted aircraft. As a result, whenever attacking fighters found themselves engaged by a SAM, they were pretty much on their own in defeating it. That suggested to at least some participating aircrews the value of having a few HARMs uploaded on selected aircraft in every strike package so that strikers could protect themselves as necessary without having to depend in every case on support from F-16CJs or EA-6Bs.[31]

The commander of the Marine EA-6B detachment at Aviano commented that allied SEAD assets had no single-solution tactic to employ against enemy systems: 'If we try to jam an emitter in the south, there may

be a northern one that can relay the information through a communications link and land line. They are fighting on their own turf and know where to hide.'[32] He added that Serb SAM operators would periodically emit with their radars for 20 seconds and then shut down the radars to avoid swallowing a HARM.

In all, more than 800 SAMs reportedly fired at NATO aircraft, both manned and unmanned, over the course of the 78-day air war, including 477 SA-6s and 124 confirmed man-portable infrared missiles.[33] A majority of the fixed SAMs were fired without any radar guidance. Despite that expenditure of assets, enemy fire downed only two NATO aircraft – the F-117 mentioned above and, later, an F-16 – although another F-117 sustained light damage from a nearby SA-3 detonation and two A-10s were hit by enemy AAA fire but not downed.[34] Also, in two reported cases short-range, infrared-guided missiles hit A-10s, one of the missiles apparently striking the bottom of the aircraft, defusing itself, and bouncing off harmlessly.[35] US and NATO aircraft fired at least 743 HARMs against radars supporting these enemy SAMs.[36] Yet, enough of the Serb IADS remained intact – mainly the persistent AAA and MANPADS threat – to require NATO fighters to operate above a 15,000-foot floor throughout most of the air effort. Although allied pilots could effectively counter the older SA-7 with flares if they saw it in time, the SA-9/13, SA-14, SA-16, and SA-18 presented a more formidable threat.

THE BALANCE SHEET FOR KOSOVO

In the end, as noted above, enemy SAM fire brought down only two aircraft (both American), thanks to allied reliance on electronic jamming, towed decoys, and countertactics to negate enemy surface-to-air defenses.[37] However, NATO never fully succeeded in neutralising the Serb IADS, and NATO aircraft operating over Serbia and Kosovo were always within the engagement envelopes of enemy SA-3 and SA-6 missiles—envelopes that extended as high as 50,000 feet. Because of that persistent threat, mission planners had to place such high-value surveillance-and-reconnaissance platforms as the U-2 and JSTARS in less-than-ideal orbits to keep them outside the lethal reach of enemy SAMs. Even during the operations final week, NATO spokesmen conceded that they could confirm the destruction of only three of Serbia's approximately 25 known mobile SA-6 batteries.[38]

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In all events, by remaining dispersed and mobile, and by activating their radars only selectively, the Serb IADS operators yielded the short-term tactical initiative in order to present a longer-term operational and strategic challenge to allied combat sorties. The downside of that inactivity for NATO was that opportunities to employ the classic Wild Weasel tactic of attacking enemy SAM radars with HARMs while SAMs guided on airborne targets were 'few and far between.'[39] Lt Gen Michael Short, the Allied Force air commander, later indicated that his aircrews were ready for a wall-to-wall SAM threat like the one encountered over Iraq during Desert Storm but that 'it just never materialised. And then it began to dawn on us that . . . they were going to try to survive as opposed to being willing to die to shoot down an airplane.'[40]

One may also explain the dearth of enemy radar-guided SAM activity, at least in part, by reports that the Air Force's Air Combat Command had conducted information operations by inserting viruses and deceptive communications into the enemy's computer system and microwave net.[41] Although US information operators probably could not insert malicious code into enemy SAM radars themselves, General Jumper

later confirmed that Allied Force had seen the first use of offensive computer warfare as a precision weapon in connection with broader US information operations against enemy defences. As he put it, 'We did more information warfare in this conflict than we have ever done before, and we proved the potential of it.'[42]

During Desert Storm, by means of computer penetration, high-speed decrypting algorithms, and taps on landlines passing through friendly countries, the United States reportedly intercepted and monitored Iraqi E-mail and digitised messages but engaged in no manipulation of enemy computers. During Allied Force, however, information operators allegedly succeeded in putting false targets into the enemy's air defence computers to match what enemy controllers were predisposed to believe. Such activities also supposedly occasioned the classic operator-versus-intelligence conundrum from time to time, in which intelligence collectors sought to preserve enemy threat systems that provided them with streams of information while operators sought to attack and negate them in order to protect allied aircrews.[43]

All of this raised basic questions about the adequacy of US SEAD tactics, suggesting a need for better real-time intelligence on mobile enemy SAMs. We not only needed to get that information to pilots quickly enough for them to act on it, but also needed to give them greater standoff-attack capability. The downings of the F-117 and F-16 were both attributed to breakdowns in procedures aimed at detecting enemy IADS threats in a timely manner and ensuring that pilots did not fly into lethal SAM envelopes unaware of them. Other factors cited in the two downings included poor mission planning and improper use of available technology. Although far fewer aircraft were lost during Allied Force than expected, these instances pointed up some systemic problems in need of fixing.

THE WAGES OF PAST NEGLECT

The unsettling SEAD experience of Allied Force sent a much-needed wake-up call to the Air Force's EW community. The survival tactics used to such maddening effect against NATO's aircrews by Serb IADS operators were first developed and tested in the no-fly zones of Iraq. Operations Northern and Southern Watch had steadily policed these zones ever since the coalition first showed the full extent of its capability against active SAM radars during the Gulf War. For that reason, they should have come as no surprise to the Air Force's mission planners. It is reasonable to expect more of the same as potential future opponents continue to monitor US SEAD capabilities and operating procedures, adapting their countertactics accordingly.

Thanks to Allied Force and to the heightened appreciation of possible IADS threats yet to come, Air Force leadership has acknowledged that it needs to make SEAD a renewed priority. As one general observed candidly regarding the frustrations of that experience, 'There had to be about ten things that didn't go right. But the central issue is an overall lack of preparedness for electronic warfare.'[44] Indeed, one of the first signs of that insidious trend manifested itself as far back as August 1990, when half of the Air Force's ECM pods being readied for deployment to the Arabian peninsula for Desert Storm were found to be in need of calibration or repair. Numerous later sins of neglect with respect to EW included Air Force decisions to make operational readiness inspections and Green Flag EW training exercises less demanding – decisions that naturally resulted in an atrophying of the readiness inspection and reporting of EW units, along with a steady erosion of EW experience at the squadron level. 'Now', said the above-cited general, 'they only practise reprogramming [of radar warning receivers] at the national level. Intelligence goes to the scientists and says the signal has changed. Then the scientists figure out the change for the [ECM] pod and that's it. Nobody ever burns a new bite down at the wing."[45]

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Joint Strike Fighter

Moreover, during the years since Desert Storm, the response time for engaging high-end SAM threats has grown longer rather than shorter, thanks to an absence of adequate planning and to the disappearance of a talent pool of Air Force leaders skilled in EW. One senior Air Force veteran of the Gulf War complained that 'we used to have an XOE [operational EW] branch in the Air Staff. That doesn't exist any more. We used to reprogram [ECM] pods within the wings. They don't really do that any more.'[46] During a subsequent colloquium on the Kosovo air war and its implications, former Air Force Chief of Staff Gen Michael Dugan attributed these problems to the Air Force's having dropped the ball badly in 1990, when it failed to 'replace a couple of senior officers in the acquisition and operations community who [oversaw] the contribution of electronic combat to warfighting output. The natural consequence was for this resource to go away.'[47] The challenge now confronting the Air Force leadership in this respect is to anticipate and, to the extent possible, preempt the emerging SAM threats of the early twenty-first century.

NEW SOLUTIONS

One palliative now on the horizon that portends a major boost in overall SEAD mission effectiveness is substantially reduced observability to enemy radars an inherent design feature of the next-generation F-22 and F-35 (the latter previously known as the Joint Strike Fighter).[48] Once the United States fields these new multirole combat aircraft in sufficient strength toward the end of this decade, their much-reduced radar cross sections will enhance their survivability by shrinking the effective engagement envelopes of enemy radar-directed SAMs by 95 percent or more. Provided that proper tactics and some important operating limitations are respected, that will enable the F-22 and F-35 to fly in hostile airspace and reach effective weapons-release parameters undetected.[49]

Granted, as we have already seen in the arresting case of the F-117 shootdown over Serbia in 1999, such low observability to enemy radars will not render the F-22 and F-35 fully invisible along the lines of the fanciful Romulan cloaking device of Star Trek fame. It will be impossible to operate these successor-generation stealth aircraft with complete abandon in a high-threat SAM environment. On the contrary, pilots will have to fly even the F-22 and F-35 in specific attitudes to threat radars to preclude their detection and susceptibility to risk. As a senior Air Force officer cautioned two years before the F-117 downing, stealthiness 'significantly reduces your vulnerable area, but it does not give you the freedom

to ignore the threats.[50] At some aspect angles, even the stealthiest aircraft may be at least fleetingly detectable by surface radars. Moreover, they will continue to emit infrared signatures that an enemy can exploit.

Nevertheless, such advanced low observability by radar promises to reduce substantially the range at which an enemy's acquisition radars can detect ingressing friendly aircraft from various look angles, as well as complicate the tracking of any F-22 or F-35 momentarily detected by enemy sensors. This will have the net effect of narrowing significantly any defenders window of opportunity for successfully engaging and downing such aircraft. Thus, the F-22 and F-35 can operate in high-threat areas with less intense concern for surface-to-air defenses and can fly on headings and at altitude aimed at maximising opportunities for early target acquisition.

SA-12b 'Giant' SAM launcher with missiles elevated into vertical position and engagement radar at front of vehicle still lowered in travelling position

The SA-10 and SA-12 are lethal out to a slant range of 80 nautical miles, five times the killing reach of the earlier-generation SA-3

Indeed, when coupled with astute tactics based on accurate and timely threat intelligence, even the shaping and skin treatments of currently deployed stealth aircraft have rendered today's early warning and engagement radars, as well as the SAMs that depend on them, all but useless. The resultant ability provided to joint force commanders (JFC) – the ability to conduct precision attacks with near impunity – has imparted a new edge to US airpower. The F-117 and B-2, with their first- and second-generation stealth features, now allow JFCs to conduct vital operations in the most heavily defended enemy airspace that no number of less capable aircraft can perform at acceptable risk. The F-22 and F-35 will extend that capability to an ever-larger number of deployed US aircraft. Not only will such aircraft be able to produce strategic effects early in a war, but also they will increase the leverage of nonstealthy aircraft by negating enemy radar-guided SAM threats and thus provide those latter aircraft a safer envelope within which to operate over hostile terrain.

That said, however, JFCs in future contingencies will almost surely have to contend with threats of double-digit SAMs, namely the Russian S-300PM (NATO code name SA-10) and the comparably lethal SA-12 through SA-20, well before the F-22 and F-35 begin coming on-line in operationally significant numbers. The SA-10 and SA-12 are lethal out to a slant range of 80 nautical miles, five times the killing reach of the earlier-generation SA-3.[51] One SA-10/12 site in Belgrade and one in Pristina could have provided defensive coverage over all of Serbia and Kosovo. They also could have threatened Rivet Joint, Compass Call, and other key allied aircraft such as the airborne command and control centre and the Navy's E-2C operating well outside enemy airspace.

Fortunately for NATO, the Serb IADS did not include the latest-generation SAM equipment currently available on the international arms market. Early, unsubstantiated reports, repeatedly denied by the Russian Ministry of Foreign Affairs, claimed that several weeks before the start of the bombing effort, Russia had provided Serbia with elements of between six and 10 long-range SA-10 systems, delivered without their 36D6 Clam Shell target designation and tracking radars.[52] Had those reports been valid, even the suspected presence of such SAMs in the enemy's IADS inventory would have made life far more challenging for attacking NATO aircrews[53] As Lieutenant General Short later commented darkly, 'It would have profoundly changed the balance of the threat and our ability to maintain air superiority.[54] The inescapable message here is that the Air Force cannot afford to wait for the F-22 and F-35 deployments to help solve its SEAD conundrum. It must begin coming to effective grips now with this increasingly clear and present danger.

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Beyond the stealthiness portended by the F-22 and F-35, another promising avenue for dealing with emergent SAM threats may lie in the realm of nonkinetic alternatives. To offer but a glimpse into the more intriguing possibilities in this respect, General Jumper remarked after Allied Force that although information operations remained a highly classified subject about which little could be said, the Kosovo experience suggested that 'instead of sitting and talking about great big pods that bash electrons, we should be talking about microchips that manipulate electrons and get into the heart and soul of systems like the SA-10 or the SA-12 and tell it that it is a refrigerator and not a radar.'[55] Some of the more cutting-edge variants of first-generation offensive cyber warfare, reportedly tested successfully in Allied Force, suggested the feasibility of taking down enemy SAM and other defence systems in ways that would not require putting a strike package or a HARM on critical nodes to neutralise them. Toward that end, Gen Hal Hornburg, current commander of Air Combat Command, recently reiterated the importance of looking beyond familiar solutions to this looming threat in certain portions of President George W. Bush's 'axis of evil,' where the United States might find itself engaged militarily: 'We don't just need jammers and we don't just need Block 50s. . . . We need an array of capabilities. . . . I am looking for kinetic and non-kinetic solutions. I am looking, for example, for space to be able to get down to an SA-10 and convince it to launch all missiles right now or to deny it from launching their missiles right now.'[56]

Finally, an emergent concern prompted by the less-than-reassuring SEAD experience in Allied Force was the need for better capabilities for accommodating noncooperative enemy air defenses and, more specifically, countering the novel tactic whereby enemy SAM operators resorted to passive electro-optical rather than active radar tracking. That tactic prompted Maj Gen Dennis Haines, who at the time served as Air Combat Command's director of combat weapons systems, to spotlight the need for capabilities other

than relying on radar emissions to detect SAM batteries, as well as the need to locate and identify enemy SAM sites more rapidly when they emitted only briefly.57 As one looks farther down the road, the ultimate answer to this and related challenges may entail not only continuing to get better at traditional SEAD mission applications, but also moving increasingly toward developing more sophisticated concepts of operations and fielding associated new technologies. The latter include unmanned aerial reconnaissance platforms such as Global Hawk; armed, uninhabited combat air vehicles; and possibly space systems, with a view toward rendering SEAD and DEAD either missions of last resort or unnecessary altogether.

Notes

1. This article is based upon the author's book NATO's Air War for Kosovo: A Strategic and Operational Assessment, MR-1365-AF (Santa Monica, Calif.: RAND, 2001).
2. John D. Morrocco, 'Allies Attack Iraqi Targets; Scuds Strike Israeli Cities,' Aviation Week and Space Technology, 21 January 1991, 20–22.
3. The F-4G did most of the actual HARM shooting, with jamming support provided by EF-111s, EC-130s, and EA-6Bs. The allies also utilised Marine F/A-18s heavily on opening night to back up the SEAD campaign with preemptive HARM attacks.
4. Capt Dan Hampton, 'Combat Defence Suppression: The F-4G/F-16C Wild Weasel at War,' USAF Fighter Weapons Review, Summer 1991, 4–6.
5. Thomas A. Keaney and Eliot A. Cohen, Revolution in Warfare? Air Power in the Persian Gulf (Annapolis: Naval Institute Press, 1995),119.
6. Dana Priest, 'NATO Unlikely to Alter Strategy,' Washington Post, 26 March 1999.
7. Quoted in Dana Priest, 'NATO Pilot Set to Confront Potent Foe,' Washington Post, 24 March 1999.
8. Gen John Jumper, 'Oral Histories Accomplished in Conjunction with Operation Allied Force/Noble Anvil' (Washington, D.C.: Air Force Studies and Analysis Agency, n.d.).
9. Robert Wall, 'Sustained Carrier Raids Demonstrate New Strike Tactics,' Aviation Week and Space Technology, 10 May 1999, 37.
10. Robert Wall, 'Airspace Control Challenges Allies,' Aviation Week and Space Technology, 26 April 1999, 30.
11. Tim Ripley, 'Viper Weasels,' World Air Power Journal, Winter 1999/2000, 102. The standard F-16CJ weapons loadout consisted of two AGM-88 HARMs and four AIM-120 advanced medium-range air-to-air missiles (AMRAAM).
12. Richard J. Newman, 'In the Skies over Serbia,' U.S. News and World Report, 24 May 1999, 24.
13. Comments on an earlier draft by Headquarters USAFE/ IN, 18 May 2001.
14. Cited in 'Ground Troops Lauded,' European Stars and Stripes, 6 August 1999; and 'Jumper on Air Power,' Air Force Magazine, July 2000, 41.
15. James Peltz and Jeff Leeds, 'Stealth Fighter's Crash Reveals a Design's Limits,' Los Angeles Times, 30 March 1999.
16. 'Washington Outlook,' Aviation Week and Space Technology, 3 May 1999, 21. Asked whether the aircraft's loss was caused by a failure to observe proper lessons from earlier experience, Hawley added, 'That's an operational issue that is very warm.'
17. Eric Schmitt, 'Shrewd Serb Tactics Downed Stealth Jet, U.S. Inquiry Shows,' New York Times, 11 April 1999. In subsequent testimony before the Senate Armed Services Committee, F. Whitten Peters, then the secretary of the Air Force, did confirm that enemy SAMs had downed the aircraft. See Vince Crawley, 'Air Force Secretary Advocates C-130, Predators,' Defence Week, 26 July 1999, 2.
18. See David A. Fulghum and William B. Scott, 'Pentagon Gets Lock on F-117 Shootdown,' Aviation Week and Space Technology, 19 April 1999, 28–30; and Paul Beaver, 'Mystery Still Shrouds Downing of F-117A Fighter,' Jane's Defence Weekly, 1 September 1999.
19. To bolster their case, some people noted that when an F-117 had crashed earlier at an air show near Baltimore in 1998, the Air Force had thoroughly sanitised the area and hauled off the wreckage to prevent its most sensitive features from being compromised.
20. Quoted in Vago Muradian, 'Stealth Compromised by Not Destroying F-117 Wreckage,' Defence Daily, 2 April 1999. positively determine the wreckage location, Cable News Network was on the scene, and collateral-damage issues precluded the attack. Comments on an earlier draft by Headquarters USAF/XOXS, 9 July 2001.
21. Ibid.
22. On 2 April, the Yugoslav government announced its intention to hand over pieces of the downed F-117 to Russian authorities. Robert Hewson, 'Operation Allied Force: The First 30 Days,' World Air Power Journal, Fall 1999, 18. For the record, the Air Force immediately put F-15Es on alert to destroy the wreckage with AGM-130s after confirmation of the F-117 downing, but by the time the service could positively determine the wreckage location, Cable News Network was on the scene, and collateral-damage issues precluded the attack. Comments on an earlier draft by Headquarters USAF/XOXS, 9 July 2001.
23. LANTIRN stands for low-altitude navigation and targeting infrared for night.
24. Comments on an earlier draft by Headquarters USAFE/ IN, 18 May 2001.
25. Wall, 'Airspace Control Challenges Allies,' 30.
26. Brig Gen Randy Gelwix, 'Oral Histories Accomplished in Conjunction with Operation Allied Force/Noble Anvil' (Washington, D.C.: Air Force Studies and Analysis Agency, n.d.).
27. Wall, 'Airspace Control Challenges Allies,' 30.
28. The AGM-130 could be fired from a standoff range of up to 30 nautical miles. It featured Global Positioning System satellite guidance, enhanced by terminal homing via man in the loop through live video feed data-linked to the attacking aircraft from the guiding weapon.
29. The Block 50/52 F-16CJs used for defence suppression were equipped to carry the AGM-65 Maverick missile, but they did not employ that munition in Allied Force because the pilots, given their predominant focus on making the most of the AGM-88 HARM, had not sufficiently trained for its use.
30. Gelwix, 'Oral Histories.' JSOW was employed only infrequently during Allied Force. Many of the targets assigned to the Navy were inappropriate for attack by the AGM-154's cluster-bomb variant because of collateral-damage concerns, lengthy timelines associated with attacks against mobile targets, and the munitions lack of a precise-impact timeline. William M. Arkin, 'Fleet Praises JSOW, Lists Potential Improvements,' Defence Daily, 26 April 2000.
31. Lt Col Philip C. Tissue, '21 Minutes to Belgrade,' US Naval Institute Proceedings, September 1999, 40.
32. Michael R. Gordon, 'NATO to Hit Serbs from 2 More Sides,' New York Times, 11 May 1999.
33. 'AWOS Fact Sheet,' Headquarters USAFE/SA, 17 December 1999. See also William M. Arkin, 'Top Air Force Leaders to Get Briefed on Serbia Air War Report,' Defence Daily, 13 June 2000, 1.
34. David A. Fulghum, 'Kosovo Report to Boost New JSF Jamming Role,' Aviation Week and Space Technology, 30 August 1999, 22.
35. 'Washington Outlook,' Aviation Week and Space Technology, 20 September 1999, 25.
36. 'AWOS Fact Sheet.'
37. In all, US aircraft expended 1,479 ALE-50 towed decoys during Allied Force.
38. Comments on an earlier draft by Headquarters USAFE/ IN, 18 May 2001.
39. Tim Ripley, ' 'Serbs Running Out of SAMs,' Says USA,' Jane's Defence Weekly, 2 June 1999.
40. Interview with Lt Gen Michael Short, USAF, PBS Frontline, 'War in Europe,' 22 February 2000. Serb IADS operators may have been able to trade short-term effectiveness for longer-term survivability because allied aircraft typically could not find and successfully attack fielded Serbian forces and other mobile ground targets. Had they been able to do so and kill enemy troops in large numbers, the Serb army's leadership would have insisted on a more aggressive air defence effort. That would have enabled NATO to kill more SAMs but at the probable cost of losing additional friendly aircraft.
41. David A. Fulghum, 'Serb Threat Subsides, but U.S. Still Worries,' Aviation Week and Space Technology, 12 April 1999, 24.
42. 'Jumper on Air Power,' 43.
43. David A. Fulghum, ''Yugoslavia Successfully Attacked by Computers,' Aviation Week and Space Technology, 23 August 1999, 31–34.
44. Quoted in David A. Fulghum, 'NATO Unprepared for Electronic Combat,' Aviation Week and Space Technology, 10 May 1999, 35.
45. Ibid.
46. Ibid.
47. Quoted in 'Washington Outlook,' Aviation Week and Space Technology, 23 August 1999, 27.
48. On potential F-35 SEAD applications in particular, see Edward H. Phillips, 'LockMart Eyes F-35 for AEA/SEAD Use,' Aviation Week and Space Technology, 18 March 2002, 32–33.
49. As the principal designer of the B-2 wrote several years ago with respect to these limitations, stealth in practice is a combination of low observability and tactics, the latter entailing close attention to mission doctrine, maneuver, sensor operation, and weapon application in addition to relying on the aircraft's inherent low-observability properties. 'When appropriate tactics are employed,' he added, 'survivability will be assured with or without supporting ECM.' By implication, when appropriate tactics are not employed, the survivability of a nominally stealthy aircraft is anything but assured. John Cashen, 'Stealth (and Related Issues)' (paper prepared for a conference on 'Control of the Air: The Future of Air Dominance and Offensive Strike,' sponsored by the Australian Defence Studies Centre, Canberra, Australia, 15–16 November 1999), 4.
50. Quoted in David A. Fulghum, 'Expanding Roles May Shield F-22,' Aviation Week and Space Technology, 6 January 1997, 43.
51. David A. Fulghum, 'Report Tallies Damage, Lists U.S. Weaknesses,' Aviation Week and Space Technology, 14 February 2000, 34.52. Zoran Kusovac, 'Russian S-300 SAMs 'in Serbia,' ' Jane's Defence Weekly, 4 August 1999.
53. Serbian president Slobodan Milosevic reportedly pressed the Russians hard for such equipment repeatedly, without success. Deputy Secretary of State Strobe Talbott later stated that the Clinton administration put the Yeltsin government on the firmest notice that any provision of such cutting-edge defensive equipment to Yugoslavia would have a 'devastating' effect on Russian-American relations. Michael Ignatieff, Virtual War: Kosovo and Beyond (New York: Henry Holt and Company, Inc., 2000), 109.
54. Quoted in Christopher J. Bowie, Destroying Mobile Ground Targets in an Anti-Access Environment, Analysis Centre Papers Series (Washington, D.C.: Northrop Grumman Corporation, December 2001), 4.
55. 'Jumper on Air Power,' 43.
56. Gen Hal M. Hornburg, USAF, presentation to the Air Force Association National Symposium, Orlando, Fla., 14 February 2002. Disclaimer The conclusions and opinions expressed in this document are those of the author cultivated in the freedom of expression, academic environment of Air University. They do not reflect the official position of the U.S. Government, Department of Defence, the United States Air Force or the Air University.