Air Power Studies Centre
RAAF Base
Fairbairn ACT 2600
A U S T R A L I A

Air Power Studies Centre Working Papers

Air Power Studies Centre

APSC PAPER NUMBER 53

PRECISION GUIDED MUNITIONS AND THE NEW ERA OF WARFARE

Richard P. Hallion

Introduction Undoubtedly, one of the most important developments in the history of twentieth century warfare has been the emergence of the precision weapon: the weapon which can be aimed and directed against a single target, relying on external guidance or its own guidance system.[1] Launched from aircraft, ships, submarines, and land vehicles, or even by individual soldiers on the ground, the precision weapon exemplifies the principle of the low-cost threat that

forces a high-cost and complicated defence. Actually, efforts to develop practical precision guided weapons date to the First World War, though at that time the vision of advocates for such systems far exceeded the actual technological and scientific capability needed to bring them to fruition.[2] But such weapons did appear in the Second World War, in rudimentary though significant form, and it was that experience, and the experience of successor conflicts such as Korea and Vietnam, that gave to us the generation of weapons that now are incorporated in the arsenals of many nations.

Precision: The Historical Perspective

Precision has always been recognised as an important attribute of weapon development. The noted military theorist, strategist, and historian Major General J.F.C. Fuller, considered 'accuracy of aim' one of the five recognisable attributes of weaponry, together with range of action, striking power, volume of fire, and portability. (Of all of these, he considered range to be the attribute which 'dominated the fight'.) It is worth noting that the modern precision weapon combines the attributes of accuracy, range, striking power, and portability, and it is that combination that makes it a powerful force multiplier in today's military scene.[3]

With regard to the air weapon, two quotes give some perspective on the development of precision attack in this century.[4] The first is from the former chief of the US Army Air Corps, Major General James E. Fechet, writing in 1933:

> In the past, wars' slaughter has been largely confined to armed combatants. Soldier has slain soldier. Unfortunately, in the next, despite all peace time decrees and agreements, the principal effort will be directed at trade and manufacturing centers [sic]. Obviously the airman, riding so high above the earth that cities look like ant hills, cannot aim his deadly cargo at armed males. All below will be his impartial target.[5]

The second is from Colonel Phillip Meilinger, the commander of the US Air Force's School of Advanced Airpower Studies, writing over 60 years later:

> Precision air weapons have redefined the meaning of mass ... The result of the trend towards 'airshaft accuracy' in air war is a denigration in the importance of mass. PGMs provide density, mass per unit volume, which is a more efficient measurement of force. In short, targets are no longer massive, and neither are the aerial weapons used to neutralise them. One could argue that all targets are precision targets—even individual tanks, artillery pieces, or infantrymen. There is no logical reason why bullets or bombs should be wasted on empty air or dirt. Ideally, every shot fired should find its mark.[6]

These two quotes serve as boundary references to the development and use of precision weapons in this century. The former (and the earlier quote of Fuller) reflects an attitude that accepted (if unhappily and bitterly) a philosophy of military operations typified by the large- scale imprecise bombing campaigns of the Second World War, while the latter reflects the historical lessons of air warfare since that time. Seen from another perspective, the former reflects the view that precision is attainable only through aim, while the latter reflects the experience of technological development, which has emphasised both precise aim with precision guidance and control of the weapon itself. Seeking precision through accurate aim remains an important aspect of military power projection, but the historical record indicates that the best combination is, not surprisingly, the trained operator on a smart platform with smart sensors dispensing a smart weapon. Precision, it must be remembered, is a relative word, relative to the time period about which one is concerned. For example, in the summer of 1944, 47 B–29s raided the Yawata steel works from bases in China; only one plane actually hit the target area, and with only one of its bombs. This single 500 lb general purpose bomb (which hit a powerhouse located 3,700 feet from the far more important coke houses that constituted the raid's aiming point) represented one quarter of one per cent of the 376 bombs dropped over Yawata on that mission.7 In the fall of 1944, only seven per cent of all bombs dropped by the Eighth Air Force hit within 1,000 feet of their aim point; even a 'precision' weapon such as a fighter-bomber in a 40 degree dive releasing a bomb at 7,000 feet could have a circular error (CEP) of as much as 1,000 feet.8 It took 108 B-17 bombers, crewed by 1,080 airmen, dropping 648 bombs to guarantee a 96 per cent chance of getting just two hits inside a 400 x 500 feet German power-generation plant; in contrast, in the Gulf War, a single strike aircraft with one or two crewmen, dropping two laser-guided bombs, could achieve the same results with essentially a 100 per cent expectation of hitting the target, short of a material failure of the bombs themselves.9

To better appreciate the impact - no pun intended - of precision weaponry, it is only necessary to examine trends in bombing accuracy from increasingly accurate bombing platforms equipped with increasingly advanced sighting systems used to dispense dumb bombs. The following chart looks at the case of trying to hit, with a hit probability of 90 per cent, a target measuring 60 x 100 feet using 2,000 pound unguided bombs dropped from medium altitude:10

War	Number of Bombs	Number of Aircraft	CEP (in feet)
World War II	9,070	3,024	3,300
Korea	1,100	550	1,000
Vietnam	176	44	400

By the time of the Gulf War, the capabilities of 'smart' airplanes dropping dumb bombs from low altitudes were sufficient to place an unguided munition within 30 feet of a target. However, Iraqi air defences in the Kuwait theatre of operations, characterised by large numbers of man-portable surface-to-air missiles and rapid-firing light anti-aircraft cannon, simply would not permit such routine use of the low altitude operating environment. Operations from medium altitudes (15,000 ft and higher) at longer slant ranges severely complicated bombing accuracy, particularly against targets that required essentially a direct hit to be destroyed, such as hangars, bunkers, tanks, and artillery. As one analytical study concluded:

> Medium and high-altitude bombing with unguided munitions posed problems, even with digital 'smart platforms'. First, the visual bombing pipper was 2 milliradians wide. At a slant range of 20,000 feet, typical for high-angle dive deliveries, the pipper blanked out an area on the ground 40 feet across, often hiding the target. To the resulting errors must be added bomb dispersion errors. For example, the Mk 84 [General Purpose bomb] dispersion was 5-6 milliradians. The result of both of these kinds of errors was a worst-case 160 foot miss distance, even if the pilot did everything

> right and the system worked perfectly ... Using 'smart platforms' to deliver 'dumb' bombs against point targets smaller than the circular error probable (CEP) may well require redundant targeting.[11]

The development of the precision munition and its undoubted influence upon modern military affairs is one that has sparked great debate. What anticipated changes to military affairs may be expected from the precision revolution? Is it, in fact, a revolution? Is there a continuing need for the so-called 'dumb' munition and weapon? What is the likely future role of the precision weapon vis-�-vis traditional weapon systems such as airplanes, tanks, and ships? All of these are important issues that need to be examined. The following, then, are just some of the ways in which one can regard the advent of precision weapon warfare.

Precision Weapons and National Security Decision-Making

One of the greatest advantages of the precision weapon is the confidence that it can offer a decision-maker confronted with having to contemplate using force in circumstances where so-called 'collateral damage' would be either unacceptable or call into question the viability of continued military action. Even in high- tempo, high-level-of-violence conflicts, attitudes towards both 'enemy' and 'friendly' (or 'neutral') casualties have undergone a remarkable transformation since the days of the Second World War when, for example, a single air raid could kill tens of thousands of individuals and not raise any significant moral outcry.[12] Increasingly, conflict scenarios involve the use of force in dense, population-heavy environments, where the negative publicity of misplaced weaponry could have profound implications for public opinion and policy.[13]

Adding to this problem has been a generalised lack of appreciation of how warfare has changed since the Second World War. On the eve of the Gulf War, for example, critics of proposed military action posited scenarios where tens of thousands of Iraqis would be killed by largely indiscriminate air attacks that would 'carpet bomb' population centres, particularly Baghdad. To give viewers some idea of what a 'modern' air war might be like, commentators, ironically, ran footage of Berlin and other German cities after VE Day. In fact, of course, coalition leaders had no intention whatsoever of using such a level of force against an opponent, recognising that, given the moral climate of the present day, this use of power simply would not be tolerated by the world community, or even the population of a coalition nation that engaged in such action.

But, after being briefed on the air campaign plan for the Gulf War, coalition political and military leaders were very comfortable with the notion of using precision weapons in attacks deep in the midst of major cities, once they had been assured that the accuracies claimed for such weapons were realistic and not the stuff of an overenthusiastic trade-show sales briefing. On 'opening night' of the Gulf War, for example, Baghdad was struck by two kinds of precision attackers: ship-launched cruise missiles, and air-launched laser-guided bombs. More recently, the extensive use of precision weaponry in the NATO air campaign in Bosnia without (to the author's knowledge) any collateral losses, affirmed again that this kind of attack offers decision-makers an option to exert force in circumstances that, just two decades ago, they would not have considered possible. Because of precision, decision-makers have a freedom to use military force closer to non-combatant-inhabited areas in an enemy homeland (or in enemy-occupied territory) than at any previous time in military history. They need not risk the broad-area 'seeding' of bombs characteristic of earlier wars. In a strategic sense, this can act as a powerful deterrent to an aggressor who, in previous times, might well have felt that the misery of collateral losses engendered by conflict designed to overcome aggression would itself offer some shield or defence against potential action against him. In both a strategic and tactical sense, precision robs the enemy of the material wherewithal to make war.

Further, since a precision attacker has a higher probability of scoring a hit on a target than a non- precision attacker, there is less likelihood that a target will have to be revisited or repeatedly struck. While never as 'surgical' as proponents might claim, nevertheless, precision attack offers clear advantages in reducing risk to attacking forces, another encouragement for its use in conflict situations. Additionally, for a nation unwilling to risk military personnel in delivering precision weapons to a target, the somewhat less precise but still highly accurate cruise missile is an acceptable alternative.

Even in cases where precision weapons are used, there is, of course, some risk of collateral damage and consequent public outcry. Despite targets being clearly justified, this outcry can generate negative policy impacts mitigating against subsequent use of force. In the best- known example from the Gulf War, well-publicised attacks against bridges in downtown Baghdad, coupled with a precision attack against the Al Firdos command and control bunker that killed several hundred individuals using it as a shelter, generated a political reaction that included shutting down the strategic air campaign against Baghdad for ten days. This occurred despite clear evidence that the Hussein regime was trying to reconstitute key leadership functions destroyed or degraded by previous attack.[14]

Given the nature of precision weapon warfare, education of decision-makers as to their capabilities and limitations is critically important. The majority of political leaders are individuals who come from non- military backgrounds, with the possible exception of brief periods of national service as conscripts, junior enlisted, or junior officers. There is, additionally, another form of decision-participant whose education needs to be considered: the journalist who, increasingly, lacks any military background whatsoever. Today, politicians and reporters alike are far more likely to be generalists in background, with no particular understanding of military issues or military technology.[15] With the rapidly changing state of such technology, it is incumbent that military and defence organisations offer to them opportunities to become acquainted with the broad capabilities of modern military systems. This is particularly true for precision weaponry, for such weaponry has already demonstrated that, in particular circumstances, cherished notions of how wars are to be fought and the enduring value of such military constructs as the linear battlefield are questionable at best or even archaic.

Decision-makers are particularly vulnerable to looking at military events through the prism of the most recent conflict. Prior to the Gulf War, for example, the prism for American leaders was Vietnam; accordingly, there was profound scepticism and pessimism that military action could be accomplished in such a fashion as to achieve the coalition's ends quickly and with minimal loss of life. Even military professionals had considerable doubt; the former chief of staff of the US Army, General Edward C. Meyer, estimated between 10,000 and 30,000 American casualties.[16] Now, after the Gulf War, there is some danger of the opposite: believing that future wars can be won virtually automatically with casualties as low as or lower than the Gulf. Wars are obviously situational, and the casualties that one might expect to sustain in, say, a renewed Korean war (where a major population centre - Seoul - lies in range of North Korean artillery forces) are far different than one would expect in a peacekeeping contingency, or even a renewed or different Persian Gulf war.

The Leverage of Precision Weapons: Historical Experience through Vietnam

The precision weapon, within generalised boundaries, will perform roughly equally well in all circumstances, provided a target can be identified. Time scales may change and levels of effort may change, but the end result - a victory for the force making the best use of precision - is unlikely to change unless other factors (such as loss of national will, changing international support, 'wild cards,' etc) enter play. The single most important factor is how well the decision-maker, both military and political, appreciates what precision weapons can and cannot accomplish, what mechanism or process has been established to assess the appropriateness of their use, and the rules of engagement that govern their use.

Historical experience with precision guided munitions dates back over 50 years; as might be expected, the most recent use with the most sophisticated contemporary systems offers the best expectation of what might be accomplished; nevertheless, there is a considerable body of historical experience that suggests how precision weapons have dramatically transformed military affairs. The precision weapon era may be said to date to 12 May 1943, when a Royal Air Force Liberator patrol bomber dropped a Mk 24 acoustic homing torpedo that subsequently seriously damaged the U-456, driving it to the surface where it was subsequently sunk by convoy escort vessels. On 9 September 1943, a German Fritz-X radio-guided glide bomb dropped from a Dornier Do 217 bomber sank the modern Italian battleship Roma as it steamed towards Gibraltar. By war's end, Germany and the United States had employed various proto-smart weapons in combat, including radio, radar, and television-guided bombs and missiles, against targets ranging from industrial sites to bridges and enemy shipping.

Although not often thought of as a precision weapon, the various Kamikaze attackers that first appeared in the fall of 1944 functioned much like modern anti-shipping missiles, and thus can legitimately be considered a part of the precision weapon story. The Kamikaze was the deadliest aerial anti-shipping threat faced by allied surface warfare forces in the war. Approximately 2,800 Kamikaze attackers sank 34 Navy ships, damaged 368 others, killed 4,900 sailors, and wounded over 4,800. Despite radar detection and cuing, airborne interception and attrition, and massive anti-aircraft barrages, a distressing 14 per cent of Kamikazes survived to score a hit on a ship; nearly 8.5 per cent of all ships hit by Kamikazes sank. As soon as they appeared, then, Kamikazes revealed their power to force significant changes in allied naval planning and operations, despite relatively small numbers. Clearly, like the anti- shipping cruise missile of a later era, the Kamikaze had the potential to influence events all out of proportion to its actual strength.[17]

The need to destroy precision targets such as bridges had driven development of rudimentary guided bombs in the Second World War, and Korea accelerated this interest. In Korea, Air Force B-29s dropped the Razon and the much larger and more powerful Tarzon guided bombs on North Korean bridges, destroying at least 19 of them.[18] Off the Korean coast, modified Grumman F6F-5K Hellcat drones flew from the carrier USS Boxer against North Korean bridges; the Korean bridge-bombing experience stimulated the Navy to pursue development of the postwar Bullpup program, the first mass-produced air-to-surface guided missile.[19]

Accompanying this interest in anti-surface warfare was an equivalent drive to develop precision air-to-surface and surface-to-surface weapons for anti-shipping roles. In particular, the Soviet Union pursued development of such weapons as a means of countering the tremendous maritime supremacy of the Western alliance during the Cold War. One of the most significant events in the history of precision weaponry occurred on 25 October 1967, when the Israeli destroyer Eilat, patrolling 15 miles off Port Said, was sunk by four Soviet-made Styx anti-shipping missiles fired from an Egyptian missile boat, killing or wounding 99 of its crew. The sinking of the Eilat had profound impact; one surface warfare officer remarked that 'it was reveille' to the surface Navy, and a Center for Naval Analyses study concluded: 'The threat is so great to all combatant ships of the Navy that a revolution in naval tactics may be required'.[20] Subsequent rumours that the Soviets had supplied Styx missiles to North Vietnam seriously constrained naval operations off the Vietnamese coast, particularly shore bombardment missions, and one senior naval officer called the potential Styx threat his 'worst nightmare'.[21]

The Soviet Union's alarming investment in increasingly sophisticated precision weapons, together with rapid expansion of the Soviet fleet, stimulated tremendous countermeasures. This threat directly influenced the purchase of the Grumman F-14A Tomcat, armed with six long- range Phoenix air-to-air missiles, as well as more advanced airborne and surface early warning radars and fire control systems. Chief among these was the remarkable Aegis electronically steered radar which, coupled with a new surface-to-air missile (the General Dynamics Standard), and a fast-response launcher, promised some relief from the anti-missile threat. Complementing Aegis was the creation of new shipboard gun and missile defences (notably the Phalanx and Sea Sparrow), accelerated development of new anti-submarine warfare weapons and techniques, and likewise accelerated development of the McDonnell-Douglas Harpoon, an American anti-shipping missile. But despite such corrective measures, the problems posed by newer generations of weapons such as France's sea-hugging Exocet (which demonstrated its lethality in both the Falklands and Persian Gulf fighting) or the Chinese-manufactured Silkworm, continue to confront naval planners in the present day. Indeed, it can be argued that, at best, defensive measures have kept up with the threat, not surpassed it.[22]

As the anti-shipping missile transformed war at sea, the advent of the laser-guided bomb - a result of United States Air Force-sponsored research in the mid-1960s - revolutionised precision land attack, for even in its initial rudimentary form, it could function with an average circular error of less than 20 feet from the aim point. With this kind of accuracy, the need to operate mass flights of aircraft against a single aim point at last disappeared; it was as revolutionary a development in military air power terms as, say, the jet engine or aerial refuelling.[23] Even more significantly, an aircraft dropping a laser-guided bomb could drop it from outside the majority of an enemy's air defences, thus further reducing the likelihood of incurring losses to enemy defences. First field-tested in 1968, the laser-guided bomb was a powerful force-multiplier for the United States during the bitter fighting of 1972 when North Vietnamese mechanised forces invaded South Vietnam. In fact, the modern precision weapon era may be said to have begun on 13 May 1972, when four flights of laser-guided- bomb-armed McDonnell F-4 Phantoms perfunctorily took down the Thanh Hoa bridge in North Vietnam, a notorious graveyard for dozens of strike aircraft and airmen for the previous seven years.[24]

Precision Attack in the Gulf War

The Gulf War showed how radically precision attack had transformed the traditional notion of running a military campaign and, especially, an air campaign. On opening night of the war, attacks by strike aircraft and cruise missiles against air defence and command and control facilities essentially opened up Iraq for subsequent conventional attackers. Precision attacks against the Iraqi air force destroyed it in its hangars, and precipitated an attempted mass exodus of aircraft to Iran. Key precision weapon attacks against bridges served to 'channelise' the movement of Iraqi forces and create fatal bottlenecks, and many Iraqis, in frustration, simply abandoned their vehicles and walked away.[25] Overall, postwar analysis indicated that Iraq's ability to move supplies from Baghdad to the Kuwaiti theatre of operations had dropped from a total potential capacity of 216,000 metric tons per day over a total of six main routes (including a rail line) to only 20,000 metric tons per day over only two routes, a nearly 91 per cent reduction in capacity; all others (including the railroad) had essentially been destroyed. What shipments did occur were haphazard, slow, and carried in single vehicles that were themselves so often destroyed that many Iraqi drivers simply refused to drive to the KTO.[26] This destruction had taken place in an astonishingly short time; whereas, in previous non-precision interdiction campaigns, it often took hundreds of sorties to destroy a bridge, in the Gulf War precision weapons destroyed 41 of 54 key Iraqi bridges, as well as 31 pontoon bridges hastily constructed by the Iraqis in response to the anti-bridge strikes, in approximately four weeks.[27]

In the Gulf War, only nine per cent of the tonnage expended on Iraqi forces by American airmen were precision munitions. Not quite half of this per centage - 4.3 per cent - consisted of laser-guided bombs, credited with causing approximately 75 per cent of the serious damage inflicted upon Iraqi strategic and operational targets.[28] The remaining precision munitions consisted of specialised air-to-surface missiles such as the Maverick and the Hellfire, as well as cruise missiles, anti-radiation missiles, and assorted small numbers of special weapons. It was, overall, the laser- guided bomb that dominated both the battlefield, the counter-air campaign against Iraqi airfields, strikes against command and control and leadership targets, and the anti-bridge and rail campaign. As the Gulf War Air Power Survey concluded:

> Against point targets, laser-guided bombs offered distinct advantages over 'dumb' bombs. The most obvious was that the guided bombs could correct for ballistic and release errors in flight. Explosive loads could also be more accurately tailored for the target, since the planner could assume most bombs would strike in the place and manner expected. Unlike 'dumb' bombs, LGB's released from medium to high altitude were highly accurate ... Desert Storm reconfirmed that LGB's possessed a near single-bomb target-destruction capability, an unprecedented if not revolutionary development in aerial warfare.[29]

In particular, the advent of routine around-the-clock laser bombing of fielded enemy forces in the Gulf War constituted a new phase in the history of air warfare. These attacks were not classic close air support, or battlefield air interdiction, but, instead, given the level of accomplishment over time, went far beyond the levels of effectiveness traditionally implied by such terms. Indeed, the vast majority were made in the 39 days prior to the ground operation when the coalition's land forces were, for the most part, waiting for their war to begin. Yet the Iraqi army was, in effect, mortally wounded in this time. These attacks, against Iraq's mechanised formations and artillery, can best be described as a form of strategic attack directed against unengaged but fielded enemy forces, what might be termed DEA: 'Degrade Enemy Army'.[30] The combination of laser- guided bombs from F-111Fs and F-15Es, together with Maverick missiles using imaging infrared thermal sensors fired by A-10s and F-16s were devastating, as were laser- guided bombs from British Tornadoes and Buccaneers, and AS-30L laser-guided missiles fired from French Air Force Jaguars. Particularly deadly were F-111F night 'tank plinking' strikes using 500 pound GBU-12 laser-guided bombs. On 9 February for example, in one night of concentrated air attacks, 40 F-111Fs destroyed over 100 armoured vehicles. Overall, the small 66-plane F-111F force was credited with 1,500 kills of Iraqi tanks and other mechanised vehicles. Air attacks by F-15Es and Marine A-6Es in the easternmost section of the theatre averaged over 30 artillery pieces or armoured vehicles destroyed per night.[31]

Once attack helicopters attached to surface forces entered battle, they demonstrated that such results were not limited to fixed-wing attackers. At sea, Royal Navy and US Navy helicopters destroyed numerous Iraqi small boats and military craft; 14 of 15 British Aerospace Sea Skua anti-shipping missiles launched from Westland Lynx helicopters hit their targets, a hit rate of over 93 per cent. French, British, and American gunships destroyed numerous Iraqi mechanised vehicles. McDonnell AH–64A Apache crews of one US Army aviation brigade destroyed approximately 50 Iraqi tanks in a single encounter. Another Apache unit scored 102 hits for the expenditure of 107 Hellfire missiles, a hit rate of better than 95 per cent.[32]

The reaction of Iraqi forces to direct precision air attacks indicated that the traditional powerful psychological impact of air attack had, at last, been matched by the equally powerful impact of actual destruction. Two quotes serve to highlight this, the first from an Iraqi battalion commander interrogated by a US Marine Corps intelligence specialist a month after the war ended:

> Interrogator: How many of your soldiers were killed by the air war?
>
> Iraqi Officer: To be honest, for the amount of ordnance that was dropped, not very many. Only one soldier was killed and two were wounded. The soldier that was killed did not die as a result of a direct hit, but because the vibrations of the bomb caused a bunker to cave in on top of him.
>
> Interrogator: So, then you feel the aerial bombardment was ineffective?
>
> Iraqi Officer: Oh no! Just the opposite! It was extremely effective! The planes hit only vehicles and equipment. Even my personal vehicle, a 'Waz' was hit. They hit **everything!** [emphasis in original text]33

The second is from an Iraqi general reflecting morosely on the war:

> During the Iran war, my tank was my friend because I could sleep in it and know I was safe ... During this war my tank became my enemy ... none of my troops would get near a tank at night because they just kept blowing up.34

These exchanges illustrate another aspect of precision air war, particularly as it applies to the direct attack of enemy forces: What can be identified can be targeted so precisely that unnecessary casualties are not inflicted upon an opponent. In short, war, the great waster of human life, is now significantly more humane. Increasingly, war is more about destroying or incapacitating things as opposed to people. It is now about pursuing an effects-based strategy, rather than an annihilation-based strategy, a strategy that one can control an opponent without having to destroy him.35

Deliberate Force: Reaffirmation of the Gulf Experience

Nor was the Gulf War an isolated example. From 30 August through 14 September 1995, for the first time in its history, NATO forces engaged in combat operations, against Bosnian Serbian forces in the former Yugoslavia. A total of 293 aircraft, based at 15 European locations and operating from three aircraft carriers, flew 3,515 sorties in Operation Deliberate Force, to deter Serbian aggression. Somewhat less than 700 of these sorties targeted command and control, supporting lines of communication, direct and essential targets, fielded forces, and integrated air defences. A total of 67 per cent of all such targets engaged were destroyed; 14 per cent experienced moderate to severe damage, 16 per cent light damage, and only three per cent were judged to have experienced no damage.36

In contrast to the Gulf War, the vast majority of NATO munitions employed in the Bosnian conflict were precision ones: in fact, over 98 per cent of those used by American forces. American forces employed a total of 622 precision munitions, consisting of 567 laser-guided bombs (303 GBU–10, 115 GBU–12, 143 GBU–16, and 6 GBU–24), 42 electro-optical or infrared-guided weapons (10 SLAM, 9 GBU–15, and 23 Maverick), and 13 Tomahawk Land Attack cruise missiles (TLAM). American airmen dropped only 12 'dumb' bombs, consisting of 10 Mk 83's, and 2 CBU–87's. Precision weaponry accounted for 28 per cent of NATO munitions dropped by non-US attackers. Sorties by Spanish, French, and British strike aircraft dropped 86 laser-guided bombs, and French, Italian, Dutch, and United Kingdom attackers dropped 306 'dumb' bombs. Overall, combining both the American and non-American experience in Bosnia, there were 708 precision weapons employed by NATO forces, and 318 non-precision ones; thus precision weaponry accounted for 69 per cent of the total employed in the NATO air campaign. Combined statistics of American and NATO experience indicate that the average number of precision weapons per designated mean point of impact (DMPI) destroyed was 2.8. In contrast, the average number of 'dumb' general purpose bombs per DMPI destroyed was 6.6. The average number of attack sorties per DMPI destroyed was 1.5.[37]

As a result of NATO's first sustained air strike operations, all military and political objectives were attained: safe areas were no longer under attack or threatened, heavy weapons had been removed from designated areas, and Sarajevo's airport could once again open, as could road access to the city. More importantly, the path to a peace agreement had been secured. In sum, for an overall expenditure of approximately 64 weapons per day - 69 per cent (44) of which were precision weapons - NATO forces achieved their military and political objectives. The leverage that this weaponry gave over Balkan aggressors and the recognition of what precision air attack means to decision-makers in the modern world was enunciated by former Assistant Secretary of State Richard Holbrooke after the conclusion of the campaign and the settlement of the Dayton Peace Accords:

> One of the great things that people should have learned from this is that there are times when air power - not backed up by ground troops - can make a difference. That's something that our European allies didn't all agree with. Americans were in doubt on it. It made a difference.[38]

Holbrooke's statement hints at one of the major effects of precision, namely that the traditional notion of massing a large ground force to confront an opponent, particularly on a 'field of battle,' is now rendered archaic. To a degree, throughout military history, the span of influence of ground forces was always spreading out the battle area at the expense of 'mass'. As the zone of lethality an individual soldier could command increased, the spacing between soldiers expanded as well. Such spacing meant that artillery fire, however well- targeted, nevertheless could not achieve the kind of density on a day-to-day basis to control or eliminate opposition. For example, despite a truly gargantuan leavening of artillery rounds per square yard of the Western Front during the 'Great War,' the Germans and allied forces only rarely achieved decisive effect, resulting in a war of attrition that generated millions of casualties. But the precision attacker overcomes the expansion of the linear battlefield by exercising the ability to undertake individual targeting at ranges far in excess of even the most powerful artillery. Thus airplanes, 'smart' ballistic missiles, or cruise missiles, launched hundreds of miles away from a frontline, can then pass beyond that frontline for a distance of hundreds of miles more before targeting some key enemy facility or capability that directly influences the success of enemy operations at the front itself. This is true flexibility, of a sort again unknown to previous military eras.

Precision Attack versus Light Infantry

As hinted by the Balkan experience, the advantages of precision attack are not limited to what might be termed 'traditional' encounters between massive deployed forces possessing large and vulnerable weapons such as ships, tanks, and vehicles. Indeed, recent examinations of air power applications against light infantry in typical Third World crisis conditions indicate that precision offers very high leverage whether one is dealing with a mechanised force, a guerrilla-type army in a wooded or jungle environment, or even an individual urban sniper � la Sarajevo.[39] The combination of new and enhanced sensor technology, coupled with information exchange between targeting systems and strike aircraft, helicopters, or smart missiles, can defeat threats that, in previous times, were considered too difficult to thwart without greatly widening a war effort.

Even light infantry forces generate by their operations and equipment a variety of detectable signatures - visual, chemical, infrared, electromagnetic, radar, and acoustic - that render them vulnerable to a range of active radar sensor systems (such as synthetic aperture, moving target indicator, and foliage penetrating radars), and passive air (and air-deployed ground-based) sensors (such as low light level TV, thermal imagers, multispectral analysers, engine electrical ignition, and magnetic field detectors). These signatures betray the location and, indeed, strength of enemy forces, enabling targeting systems to then direct air attacks against them. A scenario by the RAND Corporation details one possible mission against guerrillas moving heavy weapons by vehicle where many of these detection technologies might synergistically come into play:

> The JSTARS crew are directed to look for vehicle traffic along several roads. During its mission, the JSTARS' Moving Target Indicator radar detects suspicious vehicle traffic in the area of concern. This information is used to cue a UAV [Unmanned Air Vehicle] equipped with a FolPen [foliage-penetrating] radar and EO/IR [electro- optical/infrared] sensors. The UAV - using its thermal imager - detects and follows several trucks that appear to be carrying weapons. The trucks disappear into a wooded area. The UAV then uses its FolPen radar to follow the vehicles down the hidden road to an assembly area. Ground sensors are then dropped. Using acoustic and thermal imagers, remote operators are able to identify the personnel and vehicles as hostile. Tactical air (TACAIR) is called in to destroy the site.[40]

The capabilities of new detection systems are remarkable by the standards of previous conflict. One countersniper ballistic analyser, the Lifeguard sniper location system developed by the Lawrence Livermore National Laboratories, detects a sniper's bullet after the round has been fired, analyses its flight path, and then establishes the bullet track back to its point of origin, all virtually instantaneously, and with an accuracy of within two feet of where the sniper is actually located. If multiple analysers are present, this track can be refined to within one inch. With this capability, even a sniper operating in the midst of a crowded urban environment is not immune to reprisal - for example, a helicopter gunship firing its cannon on precise coordinates, or a strike aircraft releasing a laser- guided soft and lightweight sticky foam bomb that could burst in a room and kill or disable a sniper without damaging or endangering the surrounding structure or building inhabitants.[41]

Future Directions in Precision Weapon Development and Use

It is not unreasonable to expect that, in the future, a core competency of an advanced air force will be the ability to provide precision strike, with accuracies less than two metres from an aim point, to any point on the globe within, at most, several hours.[42] In many ways, the 'calculus' of modern warfare has already changed. One study, by the RAND Corporation, concluded that:

> The results of our analysis do indicate that the calculus has changed and air power's ability to contribute to the joint battle has increased. Not only can modern air power arrive quickly where needed, it has become far more lethal in conventional operations. Equipped with advanced munitions either in service or about to become operational and directed by modern C3I systems, air power has the potential to destroy enemy ground forces either on the move or in defensive positions at a high rate while concurrently destroying vital elements of the enemy's war fighting infrastructure. In short, the mobility, lethality, and survivability of air power makes it well suited to the needs of rapidly developing regional conflicts.[43]

As technology changes, the nature of the precision weapon will change as well. Increasing standoff engagement ranges is vitally important, as a means of evading ever-changing ground defences and air threats; the current Joint Stand-Off Weapon is but a first step to even more advanced systems that are likely to emerge. Already, a long-range forecasting study by the United States Air Force has identified categories of 'smaller, lighter, agile, more lethal, and more affordable' air-deployed precision weapon concepts achievable over the next ten to thirty years that could 'significantly enhance' the capabilities of the service.[44] These include advanced cruise missiles to conduct electronic countermeasures attacks, autonomous miniature munitions to stop invading armies, hard-target munitions and robotic micro-munitions to attack deeply buried hard targets, hypersonic missile concepts (on the order of 5 km/sec) to strike rapidly and at long range, and precision thermoflux weapons generating long-duration very high temperatures to destroy chemical and biological weapons of mass destruction.[45] To further degrade the effectiveness of air defences, precision weapons themselves will develop trappings of their launch systems, for example, stealth. The dividing line between what is now considered a precision-guided munition and an unmanned vehicle will increasingly blur. Aircraft dispensing such weapons will increasingly become multipurpose 'battle' aircraft, capable of being applied to multiple long-range power projection tasks. The equivalent to the 'battle plane' likely will be not the questionably survivable (if even affordable) 'arsenal ship' but, rather, the 'arsenal submarine'.[46]

Intelligence, sensor development, and targeting have always been key issues in aerial warfare, but are now of even greater importance than at any previous time.[47] Precision weapon employment requires intelligence of a sufficiently high order to enable a desired mean point of impact to be established on an individual target. In an era where, increasingly, military planners speak of conducting 'information warfare' against an opponent, the connection between intelligence, sensor suitability, targeting, and combat operations is obvious. No less significant is the importance of bomb damage assessment. This was, together with intelligence collection and analysis, one of the most controversial aspects of the Gulf War. Bomb damage assessment relates directly to campaign assessment and to issues such as scheduling revisits to targets not considered sufficiently damaged. Failures in the intelligence and BDA process almost derailed the Gulf War air and land campaigns, and caused serious concerns in the minds of policy-makers as to whether their goals were being met.[48]

The story of Iraq's robust nuclear weapons program offers a case in point. Prior to the war, failures in intelligence gathering meant that the Hussein regime had applied an astounding level of effort to developing weapons of mass destruction that was utterly unknown to the international community. Immediately prior to the war, only two nuclear targets had been identified in Iraq, one a uranium mine and the other the massive Al Tuwaitha nuclear complex. During the war, targeteers identified seven other sites subsequently attacked. But after the war, inspectors learned that Iraq had, in fact, no less than ten major nuclear research facilities; eight uranium mining, production, processing, and storage sites; 24 uranium enrichment sites; nine weaponisation sites; and 17 other sites devoted to supporting Iraq's nuclear weapons program. In sum, what had been known had been targeted and much had been destroyed, but there was simply much more that was unknown and, thus, escaped attack.[49]

The profusion of advanced sensor and intelligence gathering and exploiting platforms - space-based assets, UAVs, manned airborne systems, for example - offer the hope that many of these problems will be overcome. But it is a continuing challenge, lest failures of understanding prevent the fullest possible exploitation of the precision weapon capability now available to military forces, as well as that which will become available in the near future. Sensor development has been key to the evolution of practical precision weapons, and interest in sensors, particularly those that can penetrate foliage, penetrate adverse weather, and, literally, see through the fog, haze, and smoke over a target area, is high. Sensors fall in three broad physical categories: electromagnetic (for example, electro-optical, radio frequency, and low frequency); mechanical (acoustic, seismic, and inertial), and chemical/biological. Fusing passive and active sensors into working architectures involving space-based systems, standoff airborne systems (such as JSTARS), unmanned air vehicles, unattended ground sensors, ground and airborne command and control systems, and aircraft carrying precision weapons is a key requirement now and will obviously grow in importance in the future.[50]

Targeting offers its own particular challenges for appropriate precision weapon use. Traditionally, targeteers have emphasised the systematic destruction of a target list; in the precision weapon era, there is far greater opportunity to target key nodes of a system for destruction, thus obviating a need for greater military effort and multiple strikes into high-risk areas. Obviously, to accomplish this requires, again, the closest possible connections between the targeting and intelligence communities. Targeting also has to examine the appropriateness of precision guided munition use against a particular target. Some targets, especially those covering large areas such as warehousing, truck parks, large industrial plants, and army formations in the open, where issues of collateral damage are not a concern, may well be more suitable for attacks by aircraft carrying large numbers of dumb bombs, area denial munitions, cluster munitions, fuel-air explosives, and the like. This is particularly true of troop formations, where the shock, noise, and dislocation of air attack has essentially a paralysing and demoralising effect upon troops all out of proportion, on occasion, to the actual physical destruction achieved. In the Gulf War, for example, the most feared attacker by Iraqi forces was the B-52, a large capacity dumb-bomb-dropper capable of dispensing up to 38,250 pounds of ordnance.[51]

Though there is a continuing role for the dumb munition, as the above indicates, the reshaping of military affairs that has been wrought by the precision munition will increasingly dominate logistical and strategic planning issues. Small numbers of airlifters can bring precision weapons into a crisis region, generating levels of force projection that cannot be matched by older (and slower) forms of logistical resupply (such as so-called ‘fast’ sealift) bringing weapons more suitable to the conflicts of old, such as tanks and other armoured fighting vehicles, or large masses of infantry. The ability to field precision systems into a conflict region rapidly and to good effect - for example, the deployment of the largely experimental GBU-28 deep-earth penetrator in the Gulf War, or the US Army’s Army Tactical Missile System (ATACMS) battlefield missile system, or the RAF’s deployment of TIALD in the latter stages of the war to give the Tornado force integral laser designating ability - has already emerged as a key characteristic and signal of whether or not a nation is, in fact, a modern military power.

Though precision weapons deployed from aircraft, helicopters, battlefield missile systems, and ships and submarines off-shore undoubtedly offer a degree of leverage in warfare previously unknown, their cost is a serious concern, and one that must be addressed. Cost trends in precision weaponry are likely to force an evolutionary ‘survival of the most capable for the least cost’, particularly for those military services with scarce acquisition funding. (Such considerations in the United States killed the Aquila battlefield UAV in the 1980s, and, more recently, the Tacit Rainbow and Tri-Service Stand-off Attack Missile (TSSAM) efforts.) For example, by the year 2010, the US Army’s ATACMS will constitute but one-half of one per cent of the total American munitions inventory, but will account for 28 per cent of the total cost of that inventory.[52]

Whether such a system is thus, in fact, a suitable system for mass production is a serious question, given cheaper and more effective long-range power projection options. Looking at the air warfare case, the overall reliability and costs associated with piloted systems have traditionally been less than the costs associated with operating purely unmanned weapon systems. A case in point is that of the cruise missile, which carries a small and non-penetrating warhead and which is, once launched, incapable of being retargeted. The cruise missile does not endanger a human operator, and thus may be perfectly suitable for operations where a nation is unwilling to accept the risk of having personnel caught and interned. However, it lacks the survivability and flexibility of an aircraft carrying far more precise, larger, and penetrating laser-guided bombs, which can attack multiple aimpoints on a single pass. Additionally, there are the tremendous cost penalties associated with using such missiles, which can range from 16 to over 60 times more expensive than precision guided bombs.[53] In the Gulf War, for example, the total cost of the approximately 2,000 tons of laser-guided bombs dropped by the F-117A force was roughly $146 million; that same tonnage in Tomahawk Land Attack cruise missiles would have been $4.8 billion. Accepting for the purposes of argument that a ton of explosives delivered by a cruise missile is equivalent in military effect and significance to a ton of explosives delivered by other forms of precision weaponry, to replace all of the smart weapon tonnage delivered by the United States in the Gulf War (approximately 7,400 tons) would have required nearly $18 billion in TLAM missiles.[54]

Perhaps more intriguingly, precision weapons become themselves a justification and means to acquire more cost- effective precision-weapon platforms that can radically transform the capabilities of a nation to project power and influence, even when compared to other forms of precision attack. For example, a single sortie by a Northrop B-2A Spirit stealth bomber carrying sixteen 2,000 lb penetrating Global Positioning System-Aided Munitions (GAMs) delivers the same tonnage to a target as two nonstealthy Boeing B-52H Stratofortress sorties carrying 32 air-launched cruise missiles (ALCM) with 1,000 lb non-penetrating warheads. The cost differential of the weapons alone is $288,000 for the GAMs ($18,000 per weapon) vs $32 million for the ALCMs ($1 million per weapon); the price of ship - or submarine-launched TLAMs fired from well off-shore would be an even higher $38.4 million. Each B-2A-GAM sortie thus saves well above $31 million over using cruise missiles, thus enabling each Spirit bomber to essentially pay for itself after only 20 sorties.[55] Such cost savings, whether accumulated by substituting precision weapons for other less cost- effective precision weapons that may demand larger infrastructure investment or sortie generation, or by substituting precision weapons for large numbers of dumb weapons demanding even larger infrastructure, sortie, and even force-structure investment, can thus constitute a powerful and significant argument for development of sophisticated multimission attackers, particularly stealthy ones.

Other cost trades are less obvious; for example, it is undoubtedly cheaper to have a smart airplane drop a dumb weapon, or a dumb airplane drop a dumb weapon, but the risk of revisiting targets and the previously discussed difficulties of ensuring that the target is actually hit will almost certainly mitigate against such ‘cheap’ - and misleading - solutions. The case of the dumb platform operating an autonomous or near-autonomous smart munition is, of course, more complex and worthy of analysis. Even so - as the experience of ‘buddy’ lasing vs strike aircraft having an integral laser designating ability has shown - results favour the sophisticated attacker. (In the case of buddy lasing, the complexity and teamwork required between designator and dropper, as well as the risk from enemy defences, favours the self-contained striker such as a F-117A, or a F-111F with Pave Tack, or a Tornado with TIALD.)

The ongoing revolutions in aerospace and electro-optical technology will undoubtedly continue to shape the future evolution of the precision guided munition, nowhere more so than in efforts to overcome current limitations on precision weapon use imposed by weather conditions. Two notable development efforts designed to produce acceptable accuracies in bad-weather conditions are the Joint Direct Attack Munition (JDAM), and the Joint Stand- Off Weapon (JSOW), both of which employ Global Positioning System satellite navigation terminal guidance as their primary means of achieving precision. Both JDAM and JSOW will generate their own families of precision munitions, with widely varying warhead and mission options (ranging from penetrating hard targets to dispensing submunitions in anti-armour attacks) and JSOW even offers a powered variant that renders it, in effect, a small cruise missile.[56]

The revolution in warfare that has been brought about by the precision guided munition is one that has been a long time coming, back to the Second World War, back, even, to the experimenters of the First World War who attempted, however crudely, to develop ‘smart’ weapons to launch from airships and other craft. Used almost experimentally until the latter stages of the Vietnam conflict, the precision weapon since that time has increasingly come to first influence, then dominate, and now perhaps to render superfluous, the traditional notion of a linear battlefield. Given the experience of Iraq, the linkage of advanced sensors, advanced precision weapons, long-range combat aircraft, stealth, information technologies, and the ability to strike multiple aimpoints virtually simultaneously, offers the best hope for militarily confronting the extraordinary dangers of proliferation of weapons of mass destruction by rogue nations. It is imperative that the implications of these developments and possibilities be assessed and studied lest the unwary discover themselves targets, not shooters, in some subsequent conflict.

For further details contact Air Power Studies Centre

Endnotes

1 A version of this paper was presented at the H. Silver and Associates (UK) Ltd. Precision Guided Munitions Conference, held in London, England, on 10-11 June 1996.

2 The early history of guided weapon development is one well worth exploration. Good references include Heinz J. Nowarra, German Guided Missiles, Schiffer Military/Aviation History, Atglen, PA, 1993; J.R. Smith and Antony L. Kay, German Aircraft of the Second World War, Nautical & Aviation Publishing Company, Baltimore, MD, 1989, pp. 696-699; Rowland F. Pocock, German Guided Missiles of the Second World War, Arco Publishing Co., Inc., New York, 1967; Kenneth P. Werrell, The Evolution of the Cruise Missile, Air University Press, Maxwell AFB, AL, 1985; and William F. Trimble, Wings for the Navy: A History of the Naval Aircraft Factory, 1917-1956, Naval Institute Press, Annapolis, 1990.

3 Maj. Gen. J.F.C. Fuller, Armament and History: A Study of the Influence of Armament on History: From the Dawn of Classical Warfare to the Second World War, Charles Scribner's Sons, New York, 1945, p. 7.

4 The subject of precision attack has been a generally neglected one. For this reason, Stephen L. McFarland's America's Pursuit of Precision Bombing, 1910-1945, Smithsonian Institution Press, Washington DC, 1995, is a most welcome addition to military aviation historiography, and recently won the Stuart Symington Book Award sponsored by the Air Force History and Museums Program.

5 Maj. Gen. James E. Fechet, Ret., Flying, a volume in the Century of Progress series, The Williams & Wilkins Co., Baltimore, in cooperation with The Century of Progress Exposition, 1933, p. 135.

6 Col. Phillip S. Meilinger, 10 Propositions Regarding Air Power, Air Force History and Museums Program, Washington DC, 1995, pp. 41, 45; also published under the same title as Paper No. 36, Air Power Studies Centre, Canberra, September 1995.

7 For further details on this raid, see Richard P. Hallion, 'Prelude to Armageddon: The Troubled Beginning of the Air Offensive Against Japan', Air Power History, vol. 42, no. 3, Fall 1995, p. 46.

8 B–17 statistic from US Army Air Forces, AAF Bombing Accuracy Report #2 (8th Air Force: Operational Research Section, 1945), Chart 2, 'Distribution of Effort and Results'. I wish to thank Tami Davis Biddle and W. Hays Parks for making this information available to me. The fighter bomber statistic is from an AAF chart reprinted in the previously cited McFarland, p. 194.

9 This example is built using the experience of powerplant attacks in the European theatre of operations vs powerplant attacks in the Gulf War. The World War II data is computed on the basis of information from Maj. Gen. Heywood W. Hansell, Jr., The Strategic Air War Against Germany and Japan: A Memoir, Office of Air Force History, Washington DC, 1986, pp. 280-281.

10 HQ USAF/XOX, 'Air Power Lethality and Precision: Then and Now', Fall 1990. I wish to thank Col. John A. Warden III and then Lt. Col. David A. Deptula for making this chart available to me. The number of aircraft calculations, based on the bomb requirements, are my own.

11 Gulf War Air Power Survey (GWAPS), vol. IV, Weapons, Tactics, and Training, and Space Operations, Washington DC, 1993, p. 86.

12 For example, research undertaken by Professor Harvey M. Sapolsky and his associates at the Defence and Arms Control Studies program, Massachusetts Institute of Technology, has shown that American citizens are not only intolerant of friendly deaths in combat, but increasingly intolerant of enemy ones as well, all at the same time that they show a remarkable tolerance for high levels of domestic violence within American cities. For implications of this thought in military affairs, see Harvey M. Sapolsky, 'War Without Killing,' in Sam C. Sarkesian and John Mead Flanagin (eds.) ,US Domestic and National Security Agendas, Greenwood Press, Westport CN, 1994, pp. 27-40; and Harvey M. Sapolsky and Jeremy Shapiro, 'Casualties, Technology, and America's Future Wars,' Parameters, XXVI, no. 2, Summer 1996, pp. 119-127.

13 Some of these issues are discussed cogently in Alan Vick, David T. Orletsky, John Bordeaux, and David A. Shlapak, Enhancing Air Power's Contribution Against Light Infantry Targets, RAND, Santa Monica CA, 1996. 14 Richard G. Davis, Strategic Air Power in Desert Storm, Air Force History and Museums Program, Washington DC, 1995, p. 36.

15 This was highlighted in the United States on a talkshow discussion following the shootdown of KAL 007 by a Soviet fighter. When, in the run-up to the 1984 Presidential election, a reporter asked one potential candidate what orders he would give to American fighters intercepting an unknown aircraft approaching the United States, the candidate replied that he would ask them to 'look inside the windows' and 'see if anyone was wearing a uniform'.

16 John J. Fialka and Andy Paztor, 'Grim Calculus: If Mideast War Erupts, Air Power Will Hold Key to US Casualties', New York Times, 15 November 1990.

17 Rikihei Inoguchi, Tadashi Nakajima, and Roger Pineau's The Divine Wind: Japan's Kamikaze Force in World War II, Naval Institute Press, Annapolis, 1958, is still the best single history of the Kamikaze story.

18 Robert F. Futrell, The United States Air Force in Korea, Duell,Sloan and Pearce, Washington DC, 1983, p. 320. Razon, for range and azimuth, was far more accurate than the earlier Azon. Tarzon, a 12,000 lb bomb, had the same guidance package as Razon, but with greater mass and a much more powerful explosive charge. All of these, however, were more 'OT & E' (Operational Test and Evaluation) weapons rather than standard 'in-the- inventory-ready-to-go' military options.

19 Richard P. Hallion, The Naval Air War in Korea, Nautical and Aviation Publishing Co., Baltimore, 1986, pp. 193-96. The results were one hit, one miss, and four aborts. 20 Quoted in Malcolm Muir, Jr., Black Shoes and Blue Water: Surface Warfare in the United States Navy, 1945- 1975, Naval Historical Center, Washington DC, 1996, pp. 168, 174.

21 Ibid., p. 169. The officer in question was the then- commander of Cruiser-Destroyer Flotilla 7, Rear Admiral Elmo Zumwalt, later the Chief of Naval Operations in the Carter administration.

22 Ibid., pp. 170-194.

23 For the early history of laser-guided bomb development, see David R. Mets, Quest for a Surgical Strike: The United States Air Force and Laser Guided Bombs, Air Force Systems Command Armament Division History Office, Eglin AFB, FL, 1987.

24 Eduard Mark, Aerial Interdiction in Three Wars, Center for Air Force History, Washington DC, 1994, p. 387.

25 In one notable video clip from an Army helicopter shown after the war, a column of abandoned Iraqi vehicles, some destroyed by subsequent attack, wends its way across Kuwait. After about two minute's worth of film - which, given the apparent ground speed of the helicopter, equates to approximately three miles of congestion - the cause of the jam is apparent: a bridge destroyed by a laser-guided bomb. As an aside, it is worth noting that even in the Second World War, an era of far less precise and effective air attack, troops typically abandoned their transport when exposed to it and preferred to take their chances on foot. A good example of this is the wholesale abandonment of motor vehicles by the German Wehrmacht during the Nazi retreat from France in 1944, or, earlier in the war, the abandonment of vehicles by the French Army in the face of the Nazi assault in 1940.

26 Thomas A. Keaney and Eliot A. Cohen, Gulf War Air Power Survey: Summary Report, GPO, Washington DC, 1993, pp. 95-97. Suitably impressed by interdiction strikes, Jordanian drivers routinely charged $18,000 for risking a one-way trip to Baghdad; see Milton Viorst, 'Report from Baghdad,' New Yorker, vol. 67, no. 18, 24 June 1991, pp. 55-73.

27 DoD, Conduct of the Persian Gulf War: Final Report, p. 158. Further, not all of the 54 had been targeted, for a variety of reasons including political and humanitarian ones. For a provocative analysis of what the precision revolution means to interdiction warfare (and the interplay of air and land forces) see Lt. Col. Price T. Bingham, USAF (Ret)., 'US Air Interdiction Capability Challenges Ground War Doctrine', Armed Forces Journal International, October 1992, pp. 62-63.

28 GWAPS, vol. IV, p. 85 states that 'laser-guided munitions constituted only 6.7 per cent of bombs dropped from tactical aircraft during Desert Storm', but this statistic requires reconsideration and clarification. It does not include the 77,299 dumb bombs from B–52s. Further, this is only an American statistic, and does not include coalition bombs dropped by coalition attackers. Additionally, the '9,494' laser-guided bombs listed in this study actually include 152 missile rounds—SLAM, Skipper, and Walleye, the latter an electro-optically guided glide bomb. The 4.3 per cent reflects dividing 9,342 by the total of 219,498 bombs dropped by USAF, USN, and USMC attackers.

29 Ibid., p. 87.

30 This term represents an effort by the author and Dr. Diane Putney of the Air Force History Support Office to characterise the kinds of new attacks that took place in the Gulf War. The term DEA is that of Dr. Putney, but seems to the author to perfectly summarise what, in fact, took place, and what, in fact, can be expected of air attacks of a similar nature in future wars.

31 Lt. Col. Richard B.H. Lewis, Desert Storm—JFACC Problems Associated with Battlefield Preparation, a paper in the US Army War College Military Studies Program Paper series, AWC, Carlisle Barracks, PA, 1993, p. 19. See also Richard P. Hallion, Storm Over Iraq: Air Power and the Gulf War, Smithsonian Institution Press,

Washington DC, 1992, p. 203; Keaney and Cohen, Gulf War Air Power Survey: Summary Report, p. 155; and Reuters Transcript Report, Address of Gen. Charles Horner to the Business Executives for National Security Education Fund, 8 May 1991, Washington, DC, pp. B-7, B-8. I also wish to acknowledge with appreciation information from Brigadier General Thomas J. Lennon, USAF, who commanded the F–111Fs in the Gulf.

32 Department of the Army, 'Army Weapons System Performance in Southwest Asia', Department of the Army, Washington DC, 13 March 1991, pp. 3-4; John G. Roos, 'Sergeant Pilot Recalls First Hit Delivered by France's 'Iron Fist', Armed Forces Journal International, August 1991, p. 35. Statistic on Hellfire usage from Terry Gordy of the Rockwell Corporation.

33 John G. Heidenrich, 'The Gulf War: How Many Iraqis Died?', Foreign Policy, no. 90,Spring 1993, p. 116. A 'Waz' (Vaz) is a small Jeep-like command vehicle, an indication that literally no vehicle, no matter how small, was safe from Coalition attacks.

34 Secretary's Staff Group, Reaching Globally, Reaching Powerfully: The United States Air Force in the Gulf War, Department of the Air Force, Washington DC, September 1991, p. 41.

35 I wish to acknowledge contributions to my thinking on this issue by Col. David A. Deptula, USAF. For a more complete description of this, see his essay 'Parallel Warfare: What is It? Where Did It Come From? Why is It Important?,' in William Head and Earl H. Tilford, Jr., (eds.), The Eagle in the Desert: Looking Back on US Involvement in the Persian Gulf War, Praeger, Westport, CN, 1996, especially pp. 138-141, and his more extensive Firing for Effect: Change in the Nature of Warfare, Aerospace Education Foundation, Arlington VA, August 1995.

36 Lt. Gen. Ralph E. Eberhart, 'Airpower: An Airman's Perspective', a briefing paper prepared by AF/X0, April 1996, Slide 129. Copy in the files of the Air Force Historical Support Office, Bolling AFB, DC.

37 Statistics on NATO weapon usage is from a briefing by Lt. Gen. Michael Ryan, USAF, the commander of Allied Air Force Southern Europe, presented to the Feb 1996 Corona South meeting, Orlando, Florida. Copy in the files of the Air Force Historical Support Office, Bolling AFB, DC.

38 Transcript of statement by Richard Holbrooke to Elizabeth Farnsworth, Newshour with Jim Lehrer, PBS television, February 21, 1996.

39 See the previously cited Vick, Orletsky, Bordeaux, and Shlapak, Enhancing Air Power's Contribution Against Light Infantry Targets, passim.

40 Ibid., pp. 9-27, quote from p. 28.

41 Ibid., pp. 54-57.

42 I wish to acknowledge with appreciation discussions with Lt. Gen. George Muellner, USAF, SAF/AQ that have influenced my thinking on some of the following issues. 43 Christopher Bowie, Fred Frostic, Kevin Lewis, John Lund, David Ochmanek, and Philip Propper, The New Calculus: Analyzing Airpower's Changing Role in Joint Theater Campaigns, RAND, Santa Monica CA, 1993, pp. 83- 84.

44 The quotes are from the Scientific Advisory Board, Munitions, a volume in the New World Vistas: Air and Space Power for the 21st Century series, HQ USAF/SAB, Washington DC, 1996, p. v.

45 Ibid.

46 See, for example, John Mintz, 'New Ship Could be Next Wave in Warfare', The Washington Post, 23 June 1996. The record of ships surviving three-dimensional attackers is not a good one; previous 'arsenal ships' such as the Bismarck, Tirpitz, Prince of Wales, Mushashi, Shinano, and Yamato, succumbed to air and submarine attack, as did many lesser known ones even when protected by escorting vessels. The notion of a stand-off battle plane and an arsenal submarine are, in the author's view, altogether more useful, survivable, and practicable than the chimera of an 'arsenal ship'.

47 For some relevant case studies, see John F. Kreis, ed., Piercing the Fog: Intelligence and Army Air Forces Operations in World War II , Air Force History and Museums Program, Washington DC, 1996.

48 One recent suggestion to overcome the BDA problem is to deploy small 'parasite' winged BDA sensors from a precision munition during the terminal engagement stage of its flight; during its own terminal flight, this 'BDA glider' could then observe the resulting impact and relay via satellite whether the strike was, in fact, successful. See the previously cited SAB, Munitions, p. 37.

49 For a discussion of the Iraqi program and its implications for defence decision-making, see Robert W. Chandler with Ronald J. Trees, Tomorrow's War, Today's Decisions, AMCODA Press, McLean VA, 1996, especially chapters 2-7.

50 For a discussion of sensor development trends, see Scientific Advisory Board, Sensors, a volume in the New World Vistas: Air and Space Power for the 21st Century series, HQ USAF/SAB, Washington DC, 1996.

51 The best overall study of morale and air warfare is Group Captain A.P.N. Lambert's The Psychology of Air Power, a volume in the Royal United Services Institute Whitehall Paper series, Royal United Services Institute for Defence Studies, London, 1994. For the Gulf experience in particular, see J.M. Marcum and D. W. Cline, 'Combat Stress Reaction in Iraqi Prisoners of War', Bulletin of the Menninger Clinic, vol. 57, no. 4, Fall 1993. See also GWAPS, vol. IV, pp. 256-266.

52 Data from an Institute for Defence Analysis weapons inventory study presented in Col. David A. Deptula, 'Deep Attack/Precision Conventional Strike', a draft manuscript for the Commission on Roles and Missions, 3 March 1995, p. 18. Copies of this manuscript are in the files of the Air Force History Support Office, Bolling AFB, DC, and the Air Force Historical Research Agency, Maxwell AFB, AL.

53 The comparison is between a $1.2 million TLAM vs a $73,000 GBU-27 laser-guided bomb (16:1), a $40,000 GPS- guided Joint Direct Attack Munition (30:1), and a $18,000 GPS-Aided Munition (GAM) (67:1).

54 Details on how these statistics were derived are as follows: a Gulf War-era TLAM costs approximately $1.2 million, and delivers a 1,000 lb warhead. Thus, to match a ton of high explosive delivered by a strike airplane means using two TLAMs at a total cost of $2.4 million. F–117As dropped approximately 2,000 tons of smart bombs (approximately $73,000 per bomb). Therefore: (2,000) x ($73,000) = $146,000,000 (2,000) x ($2,400,000)= $ 4,800,000,000. Total precision tonnage dropped by American forces was approximately 7,400 tons. Therefore: (7,400) x (2 x $1,200,000) = $17,760,000,000.

55 This analysis is from 'B–2 1996: The Revolution is Here', Northrop Corporation, Pico Rivera, CA, 1996, pp. 32-33. I wish to thank Dr. Christopher J. Bowie for making this available to me. Even with the more expensive JDAM ($640,000 per load of 16 weapons, versus $288,000 per load of 16 GAMs), the B-2 still saves $31,360,000 over B–52s deploying ALCMs, or $37,760,000 over ships and submarines firing TLAMs.

56 I have drawn on information from two briefings, Lt. Col. James McClendon, USAF's 'The Joint Direct Attack Munition', and Mr. Robert Pergler's 'The Joint Stand Off Weapon', presented at the previously mentioned H. Silver and Associates (UK) Ltd.'s Precision Guided Munitions Conference. Information on receiving copies of these briefings may be obtained by writing to HSA (UK) Ltd., Africa House, 64-78 Kingsway, London, WC2B 6BD.

For further details contact Air Power Studies Centre