by Carlo Kopp

Guided Munitions

Operation Iraqi Freedom saw the Baathist regime of Iraq collapse after just three weeks of sustained and concentrated air attacks by coalition aircraft, supported by ground forces which aided in flushing out targets for air attack. It was by any measure an exceptional achievement, reflecting the maturity and sophistication of modern airpower.

While a good proportion of the combat effect achieved in Iraq can be attributed to clever deployment and use of air assets, the technology of the systems and munitions used played a no less important role. Airpower is the sum of technique and technology, and this has never been as apparent as in Operation Iraqi Freedom.

Laser Guided Munitions

The laser guided bomb was one of the pillars of the air campaign, especially the battlefield interdiction effort and close air support work performed in rural and urban environments. While the Tomahawk cruise missiles basked in the media limelight, the more pedestrian reality was that vastly cheaper laser guided and GPS aided inertially guided bombs accounted for 90% or more of the 'smart' munitions delivered. The economics of smart bomb kits under $US20,000 per round cannot be argued with.

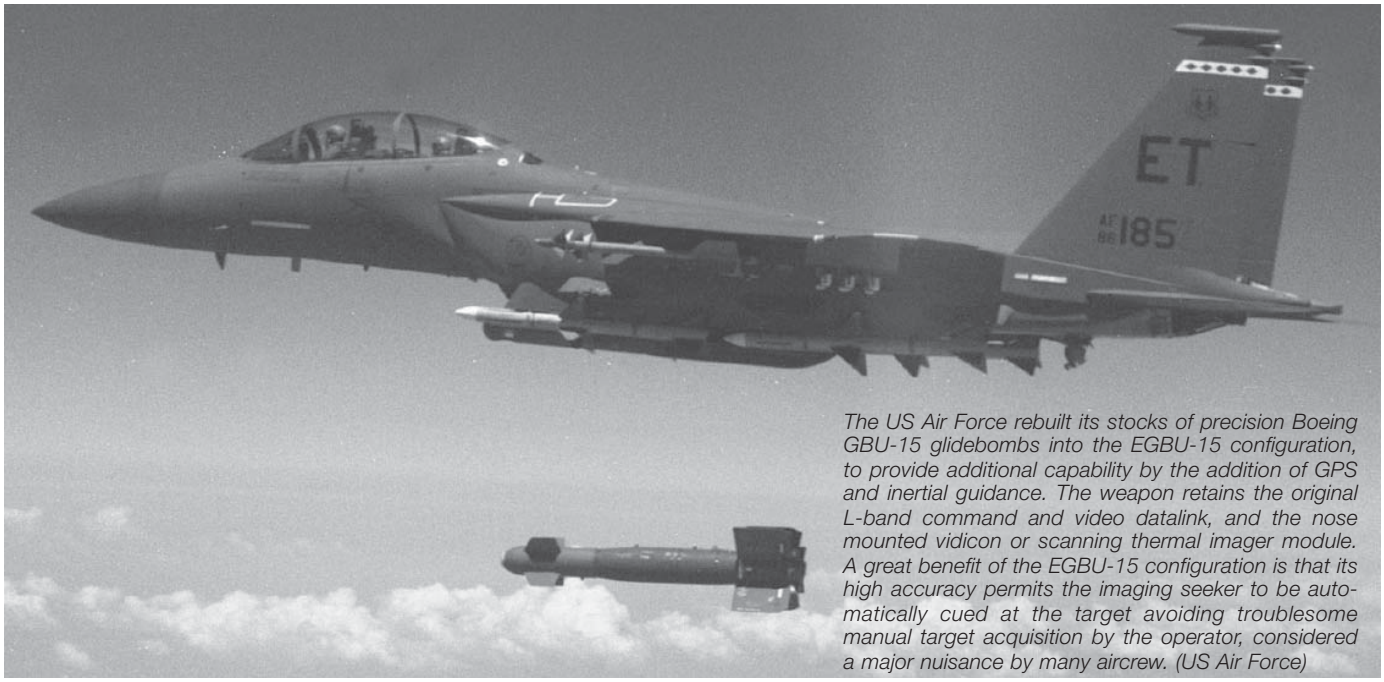
Raytheon's Paveway II/III family of Mk.82/83/84 and BLU-109/110/116/118 compatible laser guided bomb kits were without doubt the backbone of close support and battlefield interdiction work, carried by virtually all tactical aircraft used in the strike role. The weapons were by virtue of their high accuracy also used in a range of notable strategic strikes, including the 'Day 1' bunker strike, and the Basra strikes which killed over 200 Baath Party leaders and the much feared 'Chemical Ali'.

The baseline 2000lb GBU-10 and 500lb GBU-12 variants were widely used, the latter a weapon of choice for close air support due to its modest spalling* radius. The 'enhanced' GPS and inertial guidance equipped EGBU-22 and EGBU-24 supplemented stocks of baseline GBU-22/B and GBU-24G/B, while the EGBU-27/B supplemented the baseline GBU-27 Paveway III carried by the F-117A – the latter the specific weapon claimed to have been used in the initial bunker strike. With GPS/inertial capability and a Mil-Std-1760 interface, the 'enhanced' Paveway bombs revert to autonomous GPS aided inertial guidance should the laser lock be lost, upon which they behave not unlike the much cheaper JDAM – an important consideration during urban strikes where collateral damage does matter.

The heavyweight in the Paveway III family is the 5000lb GBU-28/BLU-113/B bunker buster, often dubbed 'Deep Throat'. Originally carried by the F-111F and first used in Iraq in 1991, this weapon continues to be carried by the F-15E. Based on a modified GBU-24 seeker and GBU-27 tailkit, the 'enhanced' EGBU-28 has a GPS/IMU capability and is reported to have been cleared on the Northrop Grumman B-2A's rotary launcher, providing an autonomous GPS aided deep bunker busting capability. While no disclosures have been made as to its use, the prospects are very good that quite a few were dropped in the course of the campaign.

Pre-campaign disclosures by the RAF indicated the use of a new variant of the trusty Paveway II low cost laser guided bomb. The 'EGBU-10' or 'enhanced' Paveway II improves the original 'bang-bang' laser seeker by adding a strapdown inertial midcourse package, GPS receiver and Mil-Std-1760 interface. This provides 'JDAM-like' midcourse and terminal trajectory capabilities, not unlike the EGBU-22/24, yet retains the cheap laser seeker. The result is a more reliable and accurate weapon, available in the RAF 1000lb, 'EGBU-10' 2000lb and 'EGBU-12' 500lb configurations.

(title pic) This Republic A-10A 'Hog' is departing to hunt Republican Guard armour, carrying a pair of electro-optically guided AGM-65 Maverick missiles. Manufactured in very large numbers during the Cold War as a low cost anti-tank weapon, the AGM-65 is available with a range of seekers, including daylight television, thermal imaging and semi-active laser homing. It is an extremely accurate weapon which uses television contrast lock techniques to track the target until impact. (US Air Force)



The US Air Force rebuilt its stocks of precision Boeing GBU-15 glidebombs into the EGBU-15 configuration, to provide additional capability by the addition of GPS and inertial guidance. The weapon retains the original L-band command and video datalink, and the nose mounted vidicon or scanning thermal imager module. A great benefit of the EGBU-15 configuration is that its high accuracy permits the imaging seeker to be automatically cued at the target avoiding troublesome manual target acquisition by the operator, considered a major nuisance by many aircrew. (US Air Force)

How many of the new FMU-157/B Hard Target Smart Fuses (HTSF) for the BLU-109/110/113/116 bunker busters were used remains unclear at this time – equipped with an accelerometer, it allows the fuse to be programmed to select a specific cavity within the target for detonation. The original IOC for the HTSF equipped BLU-116/B Advanced Unitary Penetrator (AUP) was March this year.

Much media attention was focused during the last days of the campaign on the planned use of Paveway laser guided bomb kits fitted to inert warheads as a low collateral damage urban strike weapon, especially useful against armour, artillery pieces, AAA/SAM systems and other point targets.

"It is not common knowledge that this technique has been used in combat previously," says Major General David Deptula of the US Air Force, originator of this technique and then commander of Operation Northern Watch and a Brigadier. He told AA of his early experiences with the technique:

"In December 1998 after Operation Desert Fox, the Iraqis began a period of increased aggression by firing AAA and SAMs at coalition aircraft enforcing the air exclusion zone in northern Iraq.

"In response, and in accordance with revised rules of engagement (ROE), the ONW [Operation Northern Watch] coalition force began responding to hostile acts against them by targeting elements of the Iraqi integrated air defense system (IADS). As the ONW forces accumulated successes in eliminating the Iraqi IADS, the Iraqi military began attempts to counter ONW force effectiveness.

"They moved most of their large SAM systems ([S-75/]SA-2s, [S-125/]SA-3s, [9M9-Kub/]SA-6s) south of the 36th parallel. In the late summer of 1999, after eight months of taking out the Iraqi IADS north of the 36th parallel, the Iraqis began to increase their attempts to 'protect' their AAA and SAMs by increased positioning of remaining AAA, and SAMs in civilian areas, and near structures such as schools, historical sites, mosques, residential areas, etc.

The GBU-12 Paveway II was by far the most widely used battlefield strike weapon, carried by all coalition fighters equipped with laser targeting equipment (left). The weapon, equipped with inert 'concrete' warheads may have been used to engage urban targets in the final days of the conflict. This APG-65 equipped Marine Corps AV-8B Harrier II (below) is armed with a single GBU-16 1000lb Paveway II. (US Air Force)

"Having used an 'effects based philosophy' in the design of the Gulf War One air campaign, I felt that using inert weapons was a viable method for negating the Iraqi effort to provide sanctuary for their weapons.

"The concept is that 500lb [225kg] (or 2000lb [900kg]) of concrete going 500 knots will ruin your whole day. With inert weapons the potential for collateral damage is reduced by several orders of magnitude – from a fragmentation pattern of thousands of feet to one of the diameter of the weapon or just slightly larger depending on the impact angle, but in every case not more than a couple of feet. Accordingly, I directed the use of inert 500lb GBU-12s and 2000lb GBU-24s against some of these targets.

"I began using this approach shortly before my tour as Commander of ONW was completed, so this approach was used in only in a couple of instances."

No trials were required to prove the technique, as the standard inert training warhead was used as a substitute for the Mk.82 or Mk.84 warheads. In the several sorties flown, Iraqi AAA sites and a French built Euromissile Roland point defence SAM system were engaged.

At the time of writing no reports were available on the operational usage in Operation Iraqi Freedom of inert round urban strike weapons – the rapid collapse of the Baathists may have seen resistance collapse before these weapons could be used in significant numbers.

It is worth noting that even physically robust targets like tanks disintegrate when the 90kg Tritonal, Minol or H-6 charge in the GBU-12's Mk.82 warhead explodes inside the vehicle, especially if a large load of main gun ammunition is carried. In an urban environment tumbling airborne 100kg pieces of tank body present a significant collateral damage hazard in their own right.

While the laser guided bomb numerically dominated in laser guided munitions, other weapons were also used widely. The US Navy and Marine Corps fired quite a few of the Raytheon AGM-65E laser guided Maverick missiles, from F/A-18s, AV-8Bs and even S-3B Vikings, the latter using 'buddy' lasing techniques. Variants of the AGM-114 Hellfire missile were the weapon of choice for the US Army's AH-64D Apache helicopters, and may have been used on some Marine Corps AH-1s.

The dominant targeting pods on US aircraft were the AN/AAQ-14 LANTIRN carried by the F-15E Beagles, F-14D Bombcats and some F-16Cs, the new Rafael IR/EO Litening II carried by Marine Corps AV-8Bs and the sole B-52H prototype installation fielded in the campaign, the Navy AAS-38A/B Nite Hawk pod on the F/A-18C/D, and most likely early examples of the Navy AN/ASQ-228 ATFLIR on F/A-18C/D and E/F aircraft. The RAF's Tornados flew with BAE TIALD pods.

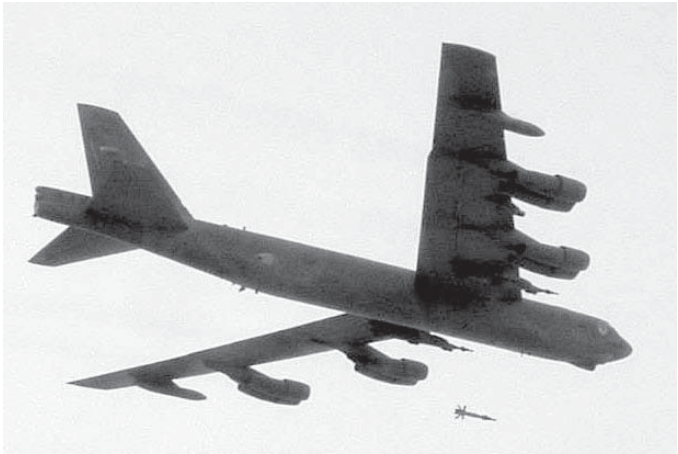
An interesting sortie during the campaign was the first strike by a laser targeting pod equipped B-52H, dropping GBU-10 laser guided bombs against two targets in the Tikrit area. This aircraft was the recently completed prototype, carrying a Rafael Litening II pod mounted on a wing pylon between the starboard engine pylons. This installation was specifically designed to address the shortcomings of blind JDAM drops during close air support and battlefield interdiction – a recognised problem in Afghanistan 18 months ago. With a potentially very large payload of 500lb and 2000lb laser guided weapons and JDAMs, and the capability to assess bomb damage effects during subsequent orbits, the B-52H makes for a fearsome 'persistent bombardment' platform over the battlefield.

Electro-Optically Guided Munitions

Electro-optically (EO) guided bombs were also likely to have been used, although numbers have yet to be disclosed.

In 1999 the US Air Force contracted an Applied Sciences Engineering/Raytheon team to perform a major upgrade on the EO/datalink guided 2000lb Boeing GBU-15 Cruciform Wing Weapon (CWW) kit stockpile, bringing these up to 'enhanced' EGBU-15 configuration with a GPS receiver, strapdown inertial package and Mil-Std-1760 interface. The EGBU-15 is more flexible, and capable of autonomous all-weather operation should the datalink channel be lost. With the impending loss of the L-band datalink frequencies used by the EGBU-15's AXQ-14 and ZSW-1 pods, the odds are very good that the existing stockpile was used generously.

The new Boeing GBU-38 500lb JDAM was first used enmasse during a B-2A strike, when a single aircraft disgorged no less than 80 rounds, each individually programmed to autonomously attack its own aimpoint (top). With a small Mk.82 warhead, the weapon is well suited to urban combat due to its smaller spalling and shrapnel footprint, compared to the standard Mk.84 2000lb GBU-31 (bottom). The weapon is planned for full scale production in 2004. (US Air Force)



This Boeing B-52H is the prototype system equipped with a Rafael Litening II laser targeting pod, which permits the B-52H to deliver laser guided weapons. The aircraft was reported to have engaged a pair of targets in the Tikrit area before the collapse of the Baathist regime. (US Air Force)

The EGBU-15's sibling is the AGM-130 – a rocket boosted derivative of the baseline weapon, which was used extensively in the 1999 and 2001 campaigns. It is also likely to have been used widely, especially where standoff range and punch were required. Both the EGBU-15 and AGM-130 are carried only by the F-15E Beagle.

A range of AGM-65 Maverick EO guided missile varaints were used, although the breakdowns on proportions of D/E/F/G thermal imaging models and AGM-65B or -65K rebuilds have not been disclosed. The weapon was also used for the first time on RAF aircraft, and photographs from the campaign show the weapon carried by AV-8Bs, Harrier GR.7s, A-10As and F/A-18Cs.

Whether the US Navy used its AGM-62 Walleye, an equivalent to the GBU-15, has not been disclosed.

Inertially Guided and GPS Aided Inertially Guided Munitions

By far the numerically most important weapon is likely to have been the Boeing GBU-31/32/35/38 Joint Direct Attack Munition (JDAM), which proved itself convincingly in the Enduring Freedom campaign of 2001, after its initial use during the 1999 bombardment of Serbia.

The weapon of choice for the B-52H and B-1B was the Boeing GBU-31 2000lb JDAM. The standard variant with the Mk.84 warhead was used most often, but the bunker busting variants with BLU-109/B or improved BLU-116/B were also applied (pictured). The US DoD has not disclosed as yet whether the BLU-118/B with a thermobaric filler was used, this variant was put to good use during Operation Enduring Freedom. (US Air Force)

The JDAM kit is currently being produced at a rate of 2800 rounds per month by Boeing in St Charles, Mo, with public reports of a pre-campaign stockpile of more than 6700 rounds. The munition comprises a standard Mk.83/84 or BLU-109/110/116/118/B warhead fitted with an inertially guided, GPS aided tailkit. Equipped with a Mil-Std-1760 umbilical, the delivering aircraft programs the weapon aimpoint, intended trajectory shape and impact geometry – once released the JDAM is wholly autonomous and oblivious to inclement weather and other traditional impediments to laser and EO/IIR guided munitions.

In terms of accuracy, the 'baseline' JDAM is considered a 'near precision' weapon. In practice, techniques such as choosing weapon time on target to coincide with the best possible satellite constellation geometry (GDOP optimisation) can drive the accuracy very close to that of older 'precision' weapons. The US Air Force has not disclosed whether the planned Wide Area GPS Enhancement (WAGE) differential GPS facility will be used – WAGE provides accuracies which are in the genuine 'precision' class.

A large proportion of the US fighter fleet is now equipped to carry JDAMs, but more significantly, the US Air Force heavy bomber fleet is now equipped for JDAM. B-2As carry up to 16 GBU-31s, B-1Bs up to 24 GBU-31s and the venerable B-52H typically 12 GBU-31s on external pylons. The combination of a large payload/range and near precision capability has given teeth to the 'transformation' argument in the heavy bombing game – the ability of a single heavy bomber to engage a dozen or more separate aimpoints on a single pass has no historical precedent.

JDAMs were the weapon of choice for the heavy bombers, but also used extensively by the F-15E, F/A-18C/D/E/F and for the first time, the F-14D. The software upgrade to deliver JDAMs from the F-14D was cleared and deployed shortly before the campaign started – interestingly enough the LANTIRN/Paveway/JDAM equipped F-14D fulfills the original US Navy intent for the strike optimised F-14C, sadly the aircraft will vanish before the decade is out.

The campaign marked the combat debut of the new 500lb GBU-38 JDAM, a weapon which is likely to become a feature of future urban bombardment campaigns. A single B-2A 'Batwing' delivered no less that 80 GBU-38s in a single pass. We can expect to see the GBU-38 proliferate rapidly across the US fighter and bomber fleets as it provides an all weather weapon which is well suited to urban combat due to its smaller spall and shrapnel footprint – full scale production is planned for 2004.

Several JDAM strikes were notable. The well publicised strike by a B-1B on one of Saddam's hideouts in Al Mansour saw four GBU-31 rounds with 25 millisecond fuse delays put into a single building, leaving little more than a crater. The fuse timing delay is characteristic for modern urban strikes, as it focuses the blast effect upwards to minimise collateral damage. Another interesting strike was an attack on Baghdad's central telephone exchange, during which the JDAMs were programmed to enter the building horizontally at ground level. TV footage showing the neat round holes in the walls illustrates just how useful this technique is, as the damage was confined to the intended floors of the building alone.

The new 2000lb BLU-116/B penetration warhead is likely to have supplemented remaining BLU-109/B stocks, and the thermobaric BLU-118/B, another BLU-109/B derivative, is also likely to have been used for some bunker targets.

The JDAM's predecessor was the Northrop Grumman GBU-36 GAM, designed for the B-2A, which evolved into the 4700lb GBU-37 with a BLU-113/B bunker busting warhead.

Two of these weapons were claimed to have been used against a Baghdad command and control bunker. Using the NG GAM/GATS targeting technique, which programs the bombs to track the same GPS satellites as the bomber, the GAM is more accurate than the baseline JDAM.

The JDAM's nearest contemporary is the Raytheon AGM-154 Joint Stand Off Weapon (JSOW), an inertially guided, GPS aided, gliding submunition dispenser. The 'baseline' AGM-154A with cluster submunitions is likely to dominate production – the anti-armour AGM-154B was reported in LRIP, and the penetrating AGM-154C's BROACH dual charge warhead was successfully tested early 2002. The JSOW has seen limited use to date primarily for defence suppression tasks, permitting the launch aircraft up to about 35 kilometres of stand off range. This weapon will have been used in Iraq, again disclosures on numbers are yet to be seen.

Recent years have also seen further conversions of retired US Air Force Boeing AGM-86B ALCM (Air Launched Cruise Missile) airframes into the conventional AGM-86C CALCM. This conversion includes a new GPS receiver and a cast explosive warhead fitted to the cavity previously occupied by the nuclear device. This weapon was used initially in 1991, and occasionally since, and may have been used in the opening days of the campaign. The WAGE differential GPS system was trailed on this weapon providing a defacto precision capability. The CALCM is carried only by the B-52H, and provides a missile which is faster, longer ranging and harder to detect than the BGM-109 Tomahawk series.

The Israeli designed Rafael/LM AGM-142, evolved from the Have Nap/Popeye series, may have also been used. Carried by the B-52H and currently being integrated on the RAAF's F-111C, this weapon provides EO/datalink guidance and up to 50nm (95km) of standoff range. Problems observed in 1999 launch attempts were traced to guidance software bugs and have since been fixed.

The US Navy made extensive use of its ship/sub launched BGM-109 Tomahawk cruise missiles, as in previous campaigns, and around 800 rounds were fired. While relatively expensive at $US1m per unit, the Tomahawk has proven to be a quite useful 'first day of the war' weapon for striking fixed targets. US Navy F/A-18C/Ds are also likely to have delivered the AGM-84E SLAM and SLAM-ER, a Harpoon derived shorter ranging cruise weapon.

The combat debut of the MBDA Storm Shadow is an important milestone for the EU's defence industry as it represents the first full scale combat use of an indigenously designed cruise missile class weapon. Using a combination of inertial, GPS and terrain profiling guidance, the Storm Shadow, derived from the French Apache family of missiles, is a shorter ranging equivalent to the AGM-86C/D CACLM, although it occupies the same market niche as the US LM AGM-158 JASSM. (UK MoD)

The Raytheon AGM-154 Joint Stand Off Weapon is a US Navy led program, yielding a GPS aided inertially guided standoff glide weapon. Three basic variants were planned for – the AGM-154A carrying cluster bomblets, the AGM-154B carrying the BLU-108 SFW submunition and the AGM-154C with a terminal seeker and unitary warhead. To date the most frequently used model has been the AGM-154A – in effect a standoff accurate cluster weapon. (US Navy)

At the time of writing no disclosures had been made about the use of pre-production Lockheed Martin AGM-158A JASSM standoff missiles. This weapon is essentially a shorter ranging cruise missile, built as a replacement for the cancelled Northrop Grumman AGM-137 TSSAM, and is a genuine low observable standoff weapon. The JASSM is currently about to enter full scale production, and Iraq would have presented a good opportunity to trial the weapon under combat conditions.

The Royal Air Force fired off around 30 of its new Matra-BAE Storm Shadow cruise missiles, a GPS/inertial/Terprom guided weapon which compares to the JASSM or CALCM, but shorter ranging than the latter. A Tornado GR.4 would typically carry a pair of weapons on the fuselage stations. The first use of the Storm Shadow is significant since it is the first modern EU built cruise missile class weapon to see operational usage.

The campaign also saw the use of more specialised weapons. The Wind Corrected Munitions Dispenser (WCMD), a kit to provide inertial corrections to SUU-65 TMD cluster dispensers, was used to deliver the Combined Effects Munition (CEM) bomblet and BLU-108/B Sensor Fused Weapon (SFW) anti-tank submunition.

The SFW was used for the first time in combat, with a B-52H delivering six weapons against a Republican Guard armoured formation. This family of weapons was devised during the latter years of the Cold War to defeat massed Soviet tank formations. The Assault Breaker program saw the use of a Pave Mover SAR/GMTI radar carried by an F-111, and later the Tacit Blue stealth demonstrator, to locate armour to be attacked by aircraft or ballistic missiles armed with the SFW.

The SFW is today deployed primarily via the SUU-66/WCMD as the CBU-105. A single SUU-66/WCMD will fly on inertial guidance to a point above the target cluster, where it cracks open and deploys ten parachute retarded BLU-108/B sumunition 'sticks' each containing four CBU-97/B or -105/B Skeet submunitions. Each stick descends to a programmed altitude, and then fires a rocket motor with canted nozzles which spins it up. At an altitude of 100 feet the BLU-108/B deploys the four SFW skeets in a cloverleaf pattern.

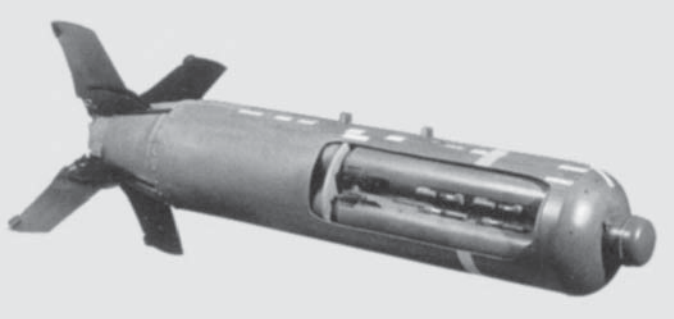
Each 13cm diameter 4kg skeet submunition is a hockey-puck shaped warhead with an Octol explosive charge and a side mounted smart fuse and infrared detector, supplemented by a solid state laser rangefinder in later variants. The skeet is unbalanced, intentionally, and wobbles as it flies. The wobbling motion results in a circular overlapping IR/laser scan pattern – when the detector recognises the characteristic infrared gradient of an armoured vehicle along its sightline, the 'sensor fuse' fires the Octol charge.

The charge vents out the top of the skeet, shaping the metal casing into a slug, and propelling the slug into the target – this is often described as the 'self forging warhead' mechanism. The metal slug punches through the top armour of the vehicle. Later variants have warhead enhancements intended to increase lethality by forming a smaller, faster slug, and spraying shards of high velocity metal produced from the outer parts of the skeet casing.

The SFW is intended to cripple rather than destroy armoured formations, as the SFW will typically aim for the AFV's engine bay – the principal infrared hot spot. However, lighter vehicles may be consumed by fire and older tanks without fire suppression systems may also burn out. Once hit by an SFW attack, an armoured formation is out of the game having lost its mobility, and vulnerable to a 'coup d'grace' attack by heavier munitions if required – the prospects are very good that most Third World armies would quickly abandon their equipment after such an attack in the field.

Conclusions

The Iraqi Freedom campaign was another 'bomber war' where airpower delivered the decisive blows against opposing ground assets. It has followed the ongoing trend to increase the fraction of guided bombs delivered, in this campaign early indications are that 80% or more of the weapons used were guided.



The Textron CBU-105 Sensor Fused Weapon permits a single heavy bomber to attack an armoured formation with up to 1200 smart submunitions, each equipped with an infrared detector, and in later versions also a laser rangefinder. Devised to cripple large Soviet armoured formations, the SFW can produce devastating effect against any large concentration of ground vehicles. (US Air Force/Textron)

The French built Euromissile Roland was the most capable SAM in the Iraqi inventory, and accounted for the sole coalition aircraft known to have been successfully engaged by an Iraqi SAM during the campaign – an A-10A Hog hit over Baghdad with the pilot safely ejecting near Baghdad Airport. The Roland has the dubious distinction of being the first SAM system to be engaged using a GBU-12 with an inert warhead, during Operation Northern Watch in 1999. (Euromissile)

There were few surprises for observers of the guided munitions market – the Enhanced Paveway and Litening II equipped B-52H being the most notable examples.

Australian observers can note that the RAAF's long running policy of favouring guided weapons is clearly vindicated. A key issue for the RAAF in the munitions game will be getting a fully qualified Mil-Std-1760 capability on the F-111C, F-111G and F/A-18A HUG as soon as possible, and 'smart' bomb racks, to permit exploitation of the JDAM, Enhanced Paveway series, and future munitions such as the Small Diameter Bomb.

It is likely that future campaigns conducted as part of the War on Terrorism will follow a similar pattern – 'bomber wars' in which the US Air Force shuts off the opponent's air defences, and a large coalition bomber force pounds the opponent's ground forces into oblivion, using targeting data provided by US intelligence, surveillance and reconnaissance assets.

Over the next decade the most useful coalition warfare air assets the RAAF will have to offer are its F-111s since these deliver twice or more the bombing punch of the F/A-18A – without the risk of burning out scarce remaining airframe hours – and are well suited to 'persistent bombardment' technique over the battlefield. While the aircraft are usable in such environments as is, their usefulness would increase significantly with the planned for EWSP upgrades, full Mil-Std-1760 capability, GBU-31/38 JDAM, and as yet unplanned for new thermal imager in the Pave Tack and datalink support for Link 16 and the US IDM protocol. The latter is now the 'datalink of choice' for close air support and persistent bombardment.

The belief held by some parties in the defence debate that coalition warfare requires that the RAAF replace its existing fighter assets with newer aircraft is patently nonsense – as the Iraqi Freedom campaign demonstrated, the RAAF's existing combat aircraft fleet will do the job and with judicious upgrades, do so even better.

Notes: observant readers would have noticed the mislabelling of the 'Day 12' map in the May AA Iraqi Freedom analysis. The map should correctly have been labelled 'Day 16'.

** Spall are molten droplets of the bomb casing and even target metal, the radius is the distance they can travel and cause lethal effect.*