Military technology

Modern laser guided bombs

Dr Carlo Kopp

The Laser Guided Bomb (LGB) remains a mainstay of modern aerial strike warfare, especially close air support operations where munitions must be delivered often in close proximity to friendly ground forces. While laser guided munitions have numerous limitations, their combination of low cost, simplicity, relatively good accuracy and ability to hit moving targets indicate that laser guided munitions will remain in use for a long time yet.

When the first LGBs were introduced by the US Air Force during the late 1960s they were employed mostly against strategic targets in North Vietnam such as bridges, bunkers, tunnel entrances and other hard targets requiring a direct hit to destroy. The reasoning was simple: reduce the exposure of aircraft to hostile anti-aircraft artillery fire, taking a heavy toll of the F-100, F-105 and F-4 fighters, which had to dive bomb such targets from low altitude to achieve any kind of accuracy. Laser guided bombs allowed attacks from much higher altitudes, and small numbers of bombs could produce up to ten times the damage effect compared with unguided or 'dumb' bombs by virtue of much greater accuracy. Lesser numbers of aircraft could thus produce the same combat effect, and do so with much lower per aircraft exposure to lethal automatic gunfire.

Late in the Vietnam conflict, LGBs were used increasingly against tactical targets along the extensive Ho Chi Minh trail resupply network. Anti-Aircraft Artillery (AAA) revetments, SA-2 missile battery sites, convoys, vehicle parks and storage sites were attacked, with the accuracy of these weapons improving per sortie combat effect and reducing loss rates. The new Pave Knife television-based targeting pods permitted laser designation of targets even as the aircraft evaded hostile fire.

The late 1970s and 1980s were a boom period for manufacturers of LGBs and targeting equipment. The US deployed the smaller and lighter daylight television AN/AVQ-23 Pave Spike targeting pod, and by the 1980s the day/night capable but much larger and heavier AN/AVQ-26 Pave Tack targeting pod, with a longwave thermal imager capable of seeing thermal emissions from vehicle engines, as well as contrast changes due to disturbed soil.

Importantly, LGBs became a central feature of Close Air Support (CAS) operations, with US Army and Marine Corps ground units being equipped with the AN/PAQ-1 (LTD) Laser Target Designator and later AN/PAQ-3 Modular Universal Laser Equipment (MULE). These were soon followed by the AN/PAQ-4, AN/PEQ-1 Special Operating Forces Laser Marker (SOFLAM), and AN/TVQ-2 (G/VLLD) Ground/Vehicle Laser Locator Designator. CAS operations were historically problematic due to the close proximity of friendly troops to targets and resulting potential for 'blue on blue' fratricide or 'friendly fire' losses. Laser guided weapons changed the whole paradigm, one which involved very low altitude strafing, dive bombing and level lay down attacks since the early 1940s.

A pair of new GBU-54 Laser JDAMs being loaded on a US Air Force F-16C at Balad AB (US DoD).

As laser designators became more widely used by ground forces for marking targets, the US Air Force deployed the AN/AAS-35 Pave Penny Laser Spot Tracker (LST) pod on the A-10 Thunderbolt and A-7D Corsair II CAS aircraft. This device placed a symbol on the pilot's Head Up Display to show the location of the laser designation thus permitting attacks using not only LGBs, but also gunfire or various unguided munitions. The US Navy and Marine Corps soon followed with the ASQ-173 Laser Spot Tracker/ Strike Camera pod for the F/A-18A/B, usually paired with a compact AAS-38 thermal imaging and laser designating pod.

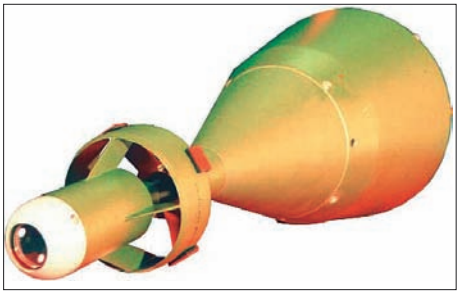
The Soviets soon followed with the deployment of the Kaira and Klen series of combined daylight laser designators and spot trackers, embedded in the noses of tactical fighters such as the MiG-27 Flogger, Su-24 Fencer and Su-22M4 Fitter. The French deployed the Thomson CSF ATLIS series of pods, comparable to the Pave Spike.

These were important developments, as they set the pattern for the evolution of targeting systems used by aircraft and helicopters, and became an enabler for the use of laser guidance in other weapons. The latter included laser guided artillery rounds such as the US M712 Copperhead and Russian Krasnopol series, tactical anti-armour missiles such as the US Hughes AGM-65 Maverick, French AS.30L and Soviet/Russian Kh-25L Karen.

Laser guidance rapidly became the technique of choice for providing precision fire support for ground forces.

The first genuinely large scale use of laser guided weapons occurred during the 1991 Desert Storm campaign, when US forces effectively annihilated Saddam's ground forces in Kuwait and Southern

Paveway II seeker (C. Kopp)



Azov 27N seeker used with KAB-500L and KAB-1500L kits.

Paveway III gimbaled seeker (C. Kopp)

Iraq, and lay waste to a wide range of strategic and infrastructure targets, using primarily LGBs. Strategic targets were attacked primarily the F-117A Nighthawk equipped with the thermal imaging DLIR/FLIR sensor, and F-111Fs equipped with the AVQ-26 Pave Tack sensor. These were supplemented by some F-4E Phantoms equipped with Pave Tack, and RAF Blackburn Buccaneers equipped with the Pave Spike pod, the latter acting as "master bombers" for formations of Tornado IDS bombers. The new AAQ-14 LANTIRN targeting pod was trialled on the F-15E Strike Eagle, and the TIALD pod was trialled on the RAF Tornado IDS. Around 1,000 tanks and armoured vehicles, and around 300 Hardened Aircraft Shelters (HAS) were claimed destroyed by LGBs.

Desert Storm also saw the debut of the new GBU-24/GBU-27 Paveway III LGB kit, which employed a high precision gimbaled laser seeker and inertial unit.

Until the advent of the Paveway III, LGBs used a very simple but limited seeker arrangement. This involved an aerodynamically stabilized seeker on a flexible mount, usually employing an annular airfoil, and a detector, which employs four identical elements installed under a hemispherical glass lens. In this arrangement the seeker module was aerodynamically aligned to point in the direction of the bombs' flight not unlike a weathercock, and the four detectors used to measure the angular error between the bomb's direction of flight and intended aimpoint, the latter a 'spot' being illuminated by the targeting laser. The pulsed near-infrared laser was encoded with a digital pattern identical to that programmed into the bomb when loaded on the aircraft, using a thumbwheel switch on the bomb seeker.

The limitations of this design approach were several. The bomb was typically unable to fly an optimal trajectory for maximum range, which was acceptable for high altitude drops, but not for low altitude drops where every mile of range mattered in terms of keeping the bomber out of reach of defensive fire. Accuracy was often problematic, especially against moving targets, during the last seconds of flight, as the aerodynamic method of aligning the seeker head lagged control inputs produced by the guidance system.

The GBU-24/GBU-27 Paveway III LGB kit was then designated the LLLGB (Low Level LGB) and was a outgrowth of experiments intended to develop an inertially guided bomb. The latter involved a bomb that would be programmed with target coordinates before launch and then fly blind through any weather conditions to impact. Pure inertial guidance proved too expensive for high accuracy weapons. A much cheaper and less accurate inertial unit, combined with a laser seeker, was more viable.

The resulting Paveway III weapon used an agile gimbaled laser detector under a glass dome, in an arrangement very similar to that used in heatseeking missiles. This allowed the detector to track the aimpoint at very high angular rates and high off-boresight angles independently of the bomb's immediate orientation and motion – within the gimbal limits of the seeker. The new seeker was mated with an inertial autopilot which would fly the bomb along an optimized proportional navigation or 'P-nav' trajectory.

This arrangement provided not only much higher accuracy than the aero-stabilised Paveway I/II seeker design, but also useful increases in range, especially where the bomb was tossed from low altitude.

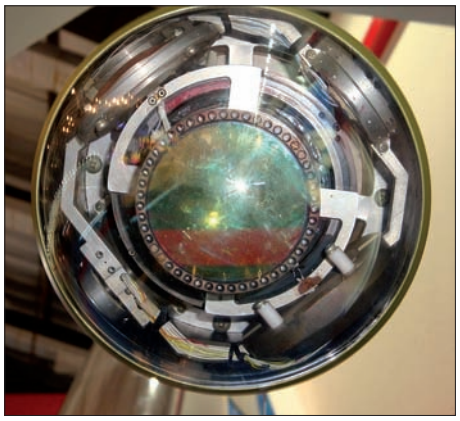
The GBU-24 and compact carriage GBU-27 were used extensively during Desert Storm and provided exceptionally high accuracy. In attacks on bunkers it was not uncommon for two bombs to be dropped, with the second round hitting close enough to exploit the weakening of the concrete produced by the first bomb. The seeker was also adapted for the two prototype GBU-28 'deep throat' 5,000 lb class bunker busters dropped by F-111Fs against critical deep bunkers used by Saddam's command staff.

The 1990s saw further proliferation of LGB technology globally. When NATO forces became embroiled in the Balkans conflict in 1999, LGBs were the dominant smart weapon in use, and the GPS/inertially guided GBU-31/32 JDAM was only then entering full rate production.

The foul weather conditions in the Balkans presented an unexpected challenge for NATO air power. During Desert Storm, the Middle Eastern desert environment presented more than often optimal delivery conditions for LGBs – an absence of cloud obscuring targets, and high infrared contrast especially at night when the desert terrain cooled rapidly. Targets were easy to find and the pristine desert atmosphere allowed laser illumination to be cleanly detected and tracked by the bomb seekers at maximum design ranges.

The Balkans were the opposite of this. Most of the Operation Allied Force campaign was fought with dense cloud cover over the Balkans, and many targets were in smog laden industrialized urban areas, with densely populated areas near targets. Often LGB attacks could not be prosecuted due to cloud blocking the line of sight to the intended target, or precipitation or haze making targets hard to identify. On many other occasions, LGBs lost seeker lock and went ballistic due to cloud, rain or haze obscuring the illuminated laser spot the bomb was aiming for. A number of collateral damage incidents occurred with civilians killed, and in the politically charged environment of this campaign, these proved a propaganda boon for the Milosevic leadership – at the expense of NATO.

The result was the 'enhanced' Raytheon/TI EGBU-



LT-3 gimballed seeker (Zhenguan Studio)

KAB-1500L on an Su-34 Fullback.

KAB-1500LG on display at MAKS-2009 (V Kuzmin)

24/27/28 hybrid seeker which involved integration of a new digital guidance package into the existing laser seeker, which combined a low cost inertial unit, multichannel GPS receiver, and a Mil-Std-1760C digital umbilical interface. These weapons could be programmed prior to launch with the GPS coordinates of the target no differently than the JDAM, fly a range optimized shaped trajectory, and acquire the laser spot for terminal homing with high accuracy. If laser lock was lost due to obscurants the bomb would fly to the last known GPS coordinates with slightly degraded accuracy.

This arrangement proved sufficiently popular that the low cost 1970s technology Paveway II design was also re-engineered, into the Paveway IV hybrid configuration, also equipped with digital GPS/inertial guidance. While not as accurate as the EGBU-24/27/28 seekers, the Paveway IV is just as robust and can fly optimal trajectories.

The Boeing JDAM has since been adapted to provide the option of a laser seeker kit. The GBU-54 500 lb, GBU-55 1,000 lb and GBU-56 2,000 lb Laser JDAM or LJDAM sees a DSU-38/B laser seeker attached to the nose of the bomb to provide terminal homing updates to the weapon's GPS/inertial guidance tail kit.

A multimode seeker including a laser semi-active homing component is also planned for the new second generation Small Diameter Bomb or SDB II series, currently in development.

The Russians have followed much the same pattern as the US in LGB technology. The first generation GNPP KAB-500L 1,000 lb and KAB-1500L 3,000 lb weapons used aerodynamically stabilized seekers copied from the Paveway II series, and retaining all of the limitations of the Paveway II series. This year KTRV unveiled the new KTRV KAB-500/1500LG series kits, which employ a gimbaled semi-active laser homing seeker modeled on the US GBU-24/27/28 seekers. It is likely that the follow-on seeker kit will incorporate the GPS/inertial guidance technology currently marketed in the KAB-500S-E

bomb kit. Russian industry continues to supply the laser guided KTRV Kh-25ML Karen missile and the KB Tochmash/Nudelman S-25L/LB laser guided 340 mm folding fin rocket – the latter technology now being emulated by Western contractors.

China's industry is also mass-producing LGB kits. The Luoyang/CASC LT-2 or LS-500J is modeled on the Russian KAB-500L series but is sufficiently different to not be a direct clone. This weapon has been deployed on most newer PLA-AF strike aircraft, including variants of the A-5C.

A yet to be designated derivative of the LT-2 displayed at Zhuhai in 2008 uses a KAB-1500LG / GBU-24 style gimbaled laser seeker.

Much more interesting however is the new Luoyang/CASC LT-3 500 lb bomb kit, which is a fusion of ideas seen in the US JDAM and GBU-24 kits. The dual mode LT-3 bomb kit combines a satellite / inertial guidance tail kit with a gimbaled laser seeker, and is a direct equivalent to the GBU-54 LJDAM design, built for high accuracy and all

clockwise from top left:

Luoyang LT-2 on JH-7A bomber.

Luoyang LT-3 500 lb round next to LT-2 2,000 lb round – the LT-3 is "China's Laser JDAM" (Zhenguan Studio).

Luoyang LT-2 on CT equipped Q-5C variant bomber.

Undesignated LT-2 variant with gimbaled seeker design.

weather operation.

In conclusion, the current global trend is away from specialized bomb kit guidance to hybrid multimode seekers, in which laser or other seeker technology is mated with a digital autopilot and satellite / inertial guidance. These weapons will be more accurate, more robust and more flexible than the orthodox 'laser only' bomb kits, which have dominated the market since the 1970s.

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