

The Emergence of Smart Bombs

Precision-guided munitions in Vietnam wrote the book on ground attack.

By John T. Correll

The Dragon's Jaw bridge at Thanh Hoa was the toughest target in North Vietnam. It was 540 feet long and crossed the Song Ma, a river 70 miles south of Hanoi. A railroad track ran down the middle, with a highway lane on either side. The bridge rested on a massive center pillar of reinforced concrete, 16 feet in diameter. The abutments were solidly anchored in the hills on both sides of the river.

This bridge was a replacement for the original one built by the French before World War II. Viet Minh insurgents managed to destroy the first bridge in 1945 by staging a collision in the center of it by two locomotives loaded with explosives. North Vietnamese leader Ho Chi Minh presided at the opening of the new—and stronger—bridge in 1964.

At the outset of the Vietnam War, the US Joint Chiefs of Staff rated the Dragon's Jaw as No. 14 on the list of the most important targets in North Vietnam. It carried the only railroad in the North Vietnamese panhandle and was a

key link in the supply route supporting the war in the south. When the Rolling Thunder air campaign began in 1965, the bridge was selected for early attack.

On April 3, 1965, Lt. Col. Robinson Risner led a strike force of almost 80 aircraft from bases in Vietnam and Thailand against the Dragon's Jaw. The actual attack was conducted by 31 F-105s from Korat Air Base in Thailand, half of them carrying Bullpup missiles and half with 750-pound general-purpose bombs.

Planners had expected the attack to drop the bridge. However, neither the missiles nor the bombs caused any appreciable damage. One pilot said the Bullpups, which had lightweight 250-pound warheads, simply “bounced off” the target.

The next day, Risner led a restrike by 46 F-105s. This time, they left the Bullpups at home and hit the bridge with some 300 bombs, but the results were no better than before. Two further strikes in May closed the bridge briefly for repairs. Large mines, dropped up-

river by transport aircraft, floated into the bridge abutments but they had little effect.

By 1972, the Air Force and the Navy had sent 871 sorties against the Dragon's Jaw, losing 11 aircraft but failing to knock out the bridge.

In 1965, the Air Force did not have any conventional weapons with a sufficient combination of accuracy and power to destroy such targets as the Thanh Hoa bridge. The standard munitions were iron bombs, similar to those used in World War II. The Air Force had only two guided air-to-surface missiles: the Bullpup, which was controlled by radio and a joystick, and the Shrike, which homed on electronic emissions and was used against surface-to-air missile sites.

The Problem of Precision

The quest for bombing accuracy was an old story for the Air Force. The spot where an unguided gravity bomb hits the ground is a function of the direction and speed of the airplane at the point of release, the aerodynamics of the pro-



Above: The Dragon's Jaw following the successful laser-guided missile strikes of May 13, 1972.

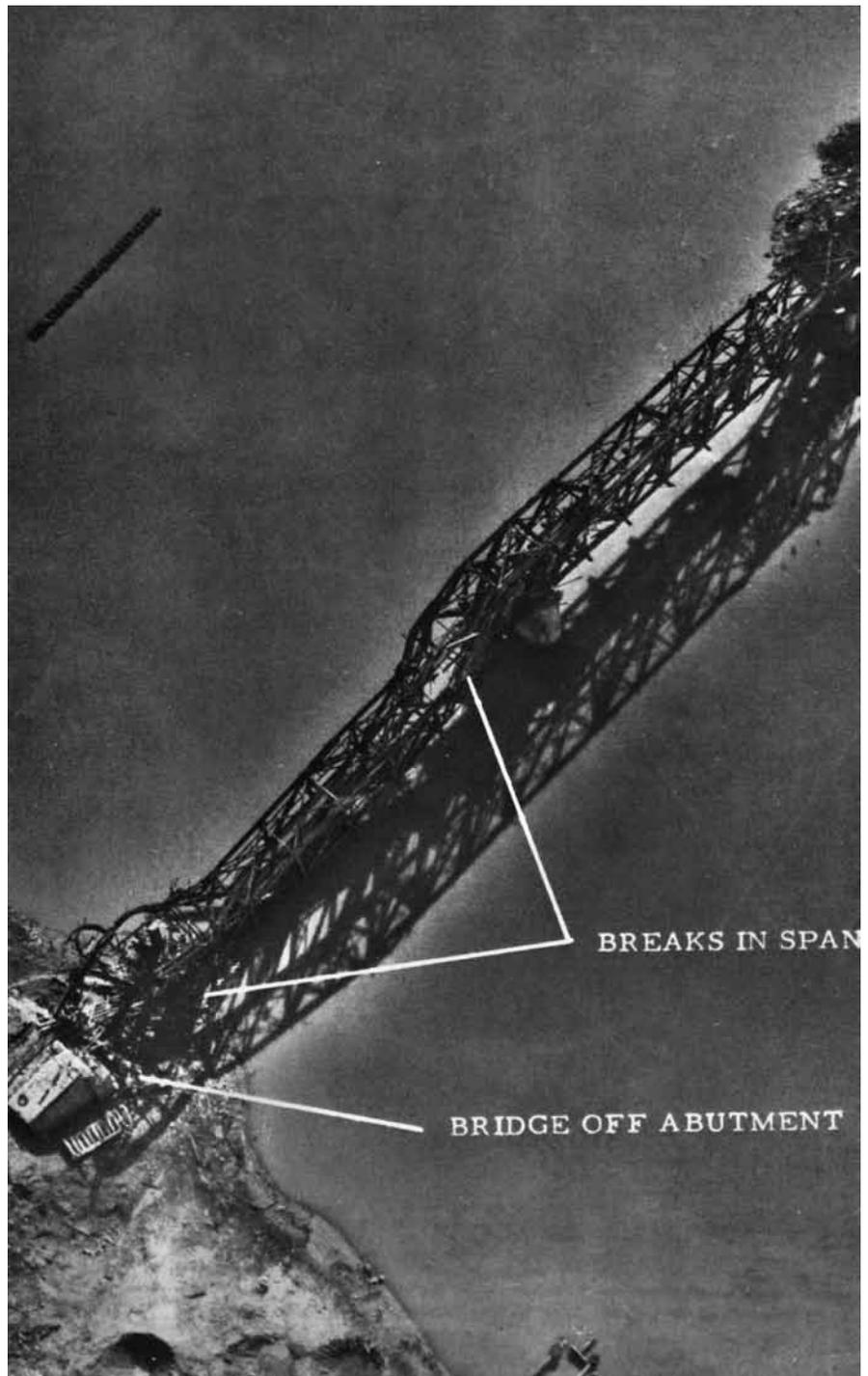
jectile, and the wind and atmospheric conditions while the bomb is in flight. A bomb dropped half a second too late can miss its target by hundreds of feet.

During World War II, it was popular to claim that Air Force bombardiers, equipped with the fabled Norden bombsight, could hit a pickle barrel from high altitude. In actuality, the average accuracy for bombers in 1943 was 1,200 feet, as measured by the standard circular error probable, or CEP. Accuracy improved to about 1,000 feet by the end of the war as aircrews gained proficiency.

For real precision, aiming was not enough. The munition had to be steered.

Both the Germans and the Americans experimented with radio-controlled weapons in World War II.

In the Korean War, the Air Force mated its Razon guidance system, which controlled range and azimuth, to the



A close-up of the damaged Thanh Hoa Bridge shows the western span knocked off its concrete abutment.

12,000-pound British Tallboy bomb for a blockbuster called the Tarzon. B-29 bombers dropped 30 Tarzons in Korea with an average accuracy of 273 feet. Tarzon was devastating to bridges but it was unreliable and unstable, which made it hazardous to use.

By the 1960s, the technology of terminal guidance for air-launched missiles had been well established. The Sidewinder air-to-air missile was a heat seeker. The Sparrow rode along a radar beam directed at enemy aircraft.

The Shrike, the weapon of the Wild Weasels, locked onto radar emissions from SAM sites. The stage was set for the emergence of precision-guided bombs.

However, "smart" bombs, unlike missiles, have no propulsion systems of their own. They are propelled only by gravity and the momentum of the launching aircraft. A seeker head locks onto the target and the flight path is adjusted by varying control fins and canards on the bomb.



Capt. Thomas Messett checks a 2,000-pound laser-guided bomb on his F-4.

The first smart bomb was the Navy Walleye in 1967. It was a free-fall bomb with a television tracking system. It required sharp contrast to lock on to the target, and was often foiled by weather and the nature of targets in Vietnam. At \$35,000 a copy, it was fairly expensive. The Air Force developed its own electro-optical glide bomb, called the Hobo (for Homing Bomb System). It had a larger warhead than Walleye, and was more accurate.

The Laser Solution

The big breakthrough in precision-guided munitions came with the laser-guided bomb. Numerous individuals and agencies had a hand in its development, but the key players were Col. Joseph Davis Jr., vice commander of the Air Proving Ground at Eglin AFB, Fla., and Weldon Word, an engineer at Texas Instruments.

Davis had come to Eglin initially as head of a detachment from USAF's Aeronautical Systems Division, exploring for technologies that promised immediate improvements to air combat in Vietnam. Average CEP bombing accuracy at the beginning of the Vietnam War was 420 feet. In 1965, Davis was looking for a weapon with the accuracy to hit routinely within 30 feet of a target and powerful enough to destroy it. He saw promise in a concept suggested by

Word, who drew on earlier research by the Army for laser guidance of missiles.

Word's idea—proposed under a streamlined program for small, fast-track projects developed for less than \$100,000—was a laser kit, consisting of seeker and guidance components that could be "bolted on" to standard gravity bombs.

The laser-guided bomb required two airplanes. The designator airplane would focus a tight laser beam on the target, painting it continuously and reflecting back outward a cone of laser energy called the basket.

A second airplane, the shooter, would drop a bomb into the basket. The bomb's seeker head locked onto the laser illumination and homed on the target.

Except for the seeker head, all of the components of Word's laser kit were off-the-shelf items. The "bang-bang" guidance system and control fins were adapted from the Shrike missile. The fins, mounted on the bomb casing in a cruciform configuration, could be switched back and forth between two positions, neutral and control. The bang-

bang name came from the noise made by the switch from one position to the other. The bomb flew a zigzag course to the target as the fins made a corrective switch every few seconds to bring the laser reflection back to the center of the seeker head's field of view. The bomb rotated slightly in flight to take some of the edge off the undulations.

The seeker head was in the nose of the bomb, inside an airflow test probe. "The probe resembled a badminton birdie, and so from then on it was dubbed the 'birdie head,'" Word said. He proposed to build a dozen prototypes for \$99,000.

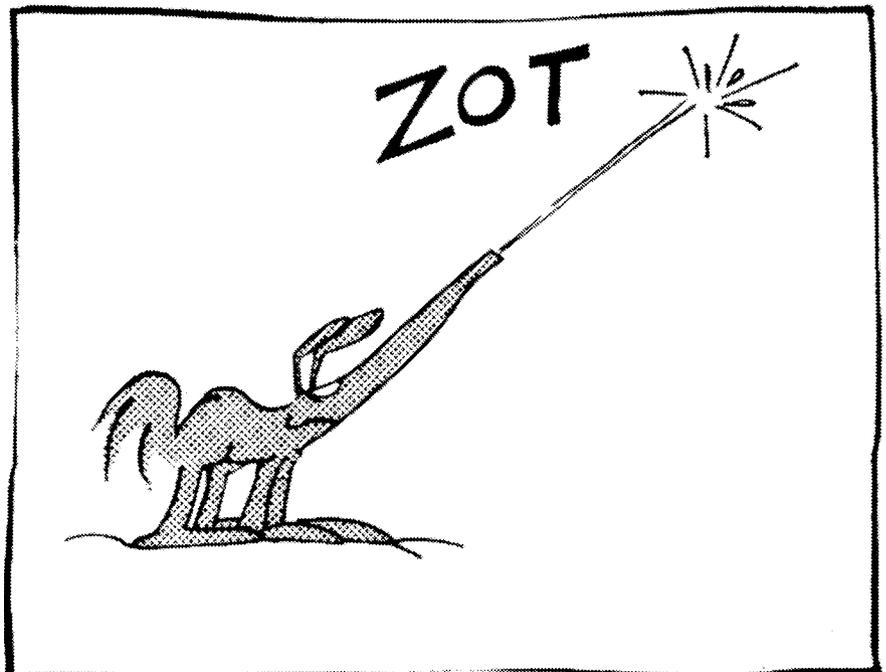
Air Force procurement officials had doubts about the Texas Instruments concept and solicited a competing offer from North American's Autonetics division. North American's design was more complex and included a gyroscope that gave the bomb a smoother flight path than the bang-bang course. However, the weapon cost three times more than the Texas Instruments PGM and it did not do as well in testing.

The contract was awarded to Texas Instruments in 1967.

From Zot to Pavé Knife

The Air Force designated the initial version of the LGB as Paveway and combat-tested it in Vietnam from May to August 1968 with the 8th Tactical Fighter Wing, flying from Ubon Air Base in Thailand.

The original device used to sight and steer the laser beam was fabricated by



The Zot laser designator was named after the sound effect attributed to the lightning-fast tongue thrust of the anteater in Johnny Hart's popular comic strip "B.C."

two Air Force officers at Eglin and was mounted on the left canopy rail of the rear cockpit of an F-4 fighter. It was called the “Zot,” after the sound effect for the lightning-fast thrust of the ant-eater’s tongue in the comic strip “B.C.”

The designator F-4 orbited the target in a pylon turn, a left bank of almost 40 degrees at an altitude of 12,000 feet, and fixed its laser beam on the target. The beam remained sharp and accurate for a distance of more than five miles. At bombing altitude, the cone of laser energy radiating outward was almost a mile in diameter. Any number of shooter aircraft could drop their bombs into the basket. The designator F-4 had to hold its illumination of the target until the bombs hit the target about 30 seconds after release.

Two Paveway variants were used in the combat testing. One bolted the laser kit onto a Mk 117 750-pound bomb, placing the control fins in the rear because of the bomb’s bulbous shape. The other variant used a Mk 84 2,000-pound bomb, which had a more dynamic shape, allowing placement of the control fins toward the front.

The Mk 117 variant had a disappointing accuracy of 75 feet in the combat testing, but the results from the Mk 84 version were spectacular. Average accuracy was 20 feet—fully a third better than Davis and Eglin had hoped for—with one in every four bombs scoring a direct hit.

And at \$3,000 each, Paveway bombs were cheap compared to the \$35,000 Walleyes.

However, before the Paveway LGB could be put into action, the White House had ordered a halt of bombing of North Vietnam. For the next four years, the new smart bombs were used only in South Vietnam and Laos, where there were not many good targets but where the Air Force gained valuable experience in training, testing, and development of tactics. In some instances, accuracy was better than 10 feet. In areas where the air defense threat was not too severe, AC-130 and OV-10 aircraft also employed LGBs.

The Air Force made considerable progress on laser-guided bombs during the bombing hiatus. A Pave Knife laser designator pod was hung from the wing of the F-4 and began to replace the Zot box for steering the laser. The pod was on a gimbal which swiveled around to keep the laser beam on the target, freeing the airplane to maneuver at will. The necessity of flying a fixed



An F-4 drops a Mk 84 laser-guided bomb. F-4s such as this one loaded with precision weapons took down the Dragon’s Jaw bridge.

orbit was eliminated. Furthermore, the designator airplane could now drop bombs as well as illuminate the target.

In the first part of the war, F-4s had been flown by two pilots. Eventually, the rear seat pilots were replaced by weapon systems officers, who were generally regarded as more skillful at lasing. They guided the laser beam with a small TV screen mounted on the instrument panel rather than with a Zot box.

The Dragon Goes Down

In 1972, “Vietnamization” of the war was in full swing. Nearly all US ground forces had been withdrawn from Southeast Asia and half of the 7th Air Force aircraft had departed.

North Vietnam saw an opportunity to win the war with a conventional attack, and on March 30 crossed the Demilitarized Zone with a large infantry and armored force in the so-called “Easter invasion.”

American airpower returned quickly to the theater and the bombing of North Vietnam resumed. The North Vietnamese supply lines were disrupted and the invasion force, unable to withstand the air assault, retreated back across the DMZ in June. The air campaign, designated Linebacker, evolved into Linebacker II.

US bombing of North Vietnam did not stop until the end of the year, having set up the peace agreement and cease-fire in January 1973.

Most of the munitions dropped by fighters and B-52s in the Linebacker campaigns were regular iron bombs, but smart bombs, including Paveway LGBs and television-guided Hobo, had an extraordinary impact. The Air Force’s Paveway capability was

concentrated at Ubon, which had only seven F-4s with Pave Knife pods and another 12 with Zot boxes. Pave Knife was essential for targets around Hanoi and Haiphong, where it was too dangerous to fly the continuous pylon turn with the Zot system. The available smart bomb aircraft were judiciously assigned to the most important targets, where they made a difference, even in small numbers.

The new precision made it possible to strike closer than before to civilian areas. Thus the Air Force could bomb the port facilities at Haiphong without danger to third country ships in the harbor. The largest power plant in North Vietnam was bombed without collateral damage to the nearby dam at the Lang Chi Reservoir. Smart bombs multiplied the effectiveness of strike sorties and took out targets that were previously too difficult—including the Dragon’s Jaw bridge at Thanh Hoa.

The Ubon F-4s attacked the Dragon’s Jaw on April 27, but heavy cloud cover prevented the use of the laser illuminators. The strike force had to employ TV-guided bombs instead of LGBs. They damaged the highway sections but failed to take down any of the spans of the bridge. The weather was better on May 13, and the invulnerability of the Dragon’s Jaw finally came to an end.

The F-4s hit the bridge with 26 laser-guided bombs, several of them heavy 3,000-pounders, and did what all of the previous attacks had not been able to do. According to an Air Force review of the action, “The western span of the bridge had been knocked completely off its 40 foot thick concrete abutment and the bridge superstructure was so critically disfigured and twisted that

rail traffic would come to a standstill for at least several months.”

The Dragon’s Jaw was still in a state of disrepair when Operation Linebacker ended in December 1972.

Laser-guided bombs also knocked down a span of the mile-long Paul Doumer Bridge across the Red River on the outskirts of Hanoi.

This bridge—longer and more famous than the Dragon’s Jaw, but a less difficult target—had been bombed often and sometimes closed for brief periods, but never for long. The smart bombs did a proper job of it. This time, the Doumer Bridge did not reopen until March 1973, when the first train in 10 months rolled across it.

Confirmation

The results from the Linebacker campaigns made an overwhelming case for smart bombs, especially laser-guided bombs. Between February 1972 and February 1973, the Air Force dropped more than 10,500 LGBs. Of these, about 5,100 were direct hits, and another 4,000 had CEP of 25 feet.

“For point targets and in good weather conditions, these weapons had nearly a single-shot kill probability,” said Gen. William W. Momyer, former commander of 7th Air Force, in his book *Airpower in Three Wars*. “If the target could be seen and the target was vulnerable to the explosive power of the weapon, the probability of damage with a single weapon was 80 to 90 percent.”

In the first three months of Linebacker, the Air Force destroyed more than 100 bridges with precision-guided munitions. An Air Force study found that LGBs were “100 to 200 times as effective as conventional bombs against very hard targets and 20 to 40 times more effective against soft and area targets.” Laser-guided bombs were used in about 10 percent of the attacks on enemy tanks but accounted for 22 percent of the tanks destroyed.

The Air Force also used Walleye and Hobo electro-optical guided bombs, but they cost more—an average of \$17,000 compared to about \$4,000 for a laser-guided bomb—and the results were not as good.

In a July 1972 message to Pacific Air Forces, Gen. John W. Vogt, 7th Air Force commander, said that “we will continue to make every effort to optimize the use of the EOGB. Nonetheless, it is apparent that in the current state of the art, the LGB is a far superior weapon system.”

Despite the record in Vietnam, the Air Force did not go all-out for laser-guided bombs. Critics argued for standoff range and launch-and-leave options, so research and development continued on several fronts. Among the weapons subsequently fielded was the excellent GBU-15, a follow-on to Hobo that mated television guidance to a Mk 84 bomb.

Unlike laser-guided bombs, the GBU-15 could be used in bad weather. The Air Force also stuck with Maverick missiles, in both television-guided and infrared variants, for use by A-10 attack aircraft against tanks.

Before the Air Force went to war again, it had made considerable progress with laser-guided bombs, fielding Paveway II (also known as the GBU-10 and GBU-12) in 1976 and Paveway III (aka GBU-24) in 1986.

The biggest visible change with Paveway II was that the tail fins folded up when carried under the airplane’s wing, then popped when the bomb was released. Two bombs could be loaded on each wing weapons station. Paveway II also had enhanced performance and more range.

New Era of Accuracy

Of greater significance was the Pave Tack targeting pod, which boresighted the laser designator to an infrared sensor for a nighttime attack capability. Paveway II and Pave Tack made their combat debut in Operation El Dorado Canyon in 1986 when F-111s employed laser-guided bombs in the raid on Libya.

Paveway III redesigned the LGB for low-level attack. The bomb could be dropped outside the basket and a scanning seeker would find the laser signal. The old bang-bang system gave way to “proportional guidance,” which adjusted the control fins to correct for small deviations detected by the seeker, resulting in a smoother flight path. The low-level GBU-24 was modified for delivery by the F-117 and designated GBU-27.

The Gulf War in 1991 marked the first extensive use of precision-guided munitions in warfare. Eight percent of the munitions dropped were PGMs, compared to less than one percent in Vietnam. The smart weapons most widely used were Paveway IIs and IIIs, and they achieved some of the most spectacular hits. New LANTIRN targeting pods

allowed additional kinds of fighters to use infrared sensors to deliver LGBs.

PGMs in the Gulf War had an average accuracy of 10 feet. The *New York Times* called the laser-guided bomb the “invention that shaped the Gulf War.”

The *Gulf War Airpower Survey* said that “Desert Storm reconfirmed that LGBs possessed a near single-bomb target-destruction capability, an unprecedented if not revolutionary development in aerial warfare.”

Operation Allied Force, the air war in Kosovo in 1999, introduced the Joint Direct Attack Munition (JDAM), which quickly became the smart bomb of choice. Like Paveway, it was a kit bomb that bolted a guidance package onto a general-purpose bomb. However, JDAM took its cues from a GPS signal from space. There was no seeker head for guidance, and no laser illumination was required. Target coordinates were loaded into the airplane’s computer before takeoff, or they could be entered or updated in flight.

Accuracy with JDAM was not as good as with Paveway, but any kind of airplane could use it 24-hours-a-day, in any kind of weather, and regardless of whether the target was obscured by smoke, camouflage, or concealment. In Allied Force, B-2 bombers put 90 percent of their JDAMs within 10 meters—or about 33 feet—of the target. Guided bombs were 35 percent of the total used, but accounted for 74 percent of the targets destroyed.

Use of smart weapons reached a new high in Operation Iraqi Freedom in 2003, when 68 percent of the munitions were guided. Of these, 22.4 percent were JDAMs and 29.5 percent were laser-guided bombs.

The new era of accuracy led to a redefinition of precision-guided munitions. To qualify as a “precision” weapon, a munition must be capable of hitting within three meters, or less than 10 feet, of the aim point. Thus JDAM is rated as “near precision.”

For targets that call for better accuracy than that, the Air Force weapons inventory has a range of electro-optical and laser-guided munitions—including the GBU-15 and numerous variants of Paveway II and III.

The classic smart bomb is still on the job, 40 years after it rewrote the book on ground attack in Vietnam. ■

John T. Correll was editor in chief of Air Force Magazine for 18 years and is now a contributing editor. His most recent article, “The Cost of Schweinfurt,” appeared in the January issue.